PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLVI—No. 1

AMERICAN
SOCIETY OF
CIVIL
ENGINEERS
FOUNDED
1852

January, 1920

Published by the American Society of Civil Engineers at its Headquarters, 33 West Thirty-ninth Street, New York, the Fourth Wednesday of each Month, except June and July.

Entered as Second-Class Matter, December 14th, 1896, at the Post Office at New York, N. Y., under the Act of March 3d, 1879.
Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3d, 1917, authorized on July 5th, 1918.
Subscription, $8 per annum.

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Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1920

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The Reading Room of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, New Year's Day, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 6 P. M.

HEADQUARTERS OF THE SOCIETY—33 WEST THIRTY-NINTH STREET, NEW YORK.

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CABLE ADDRESS......................"Ceas, New York."

Vol. XLVI. JANUARY, 1920. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PROCEEDINGS

SOCIETY AFFAIRS

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MINUTES OF MEETINGS
OF THE SOCIETY

December 17th, 1919.—The meeting was called to order at 8.30 P. M.; Vice-President Herbert S. Crocker in the chair; Chas. Warren Hunt, Secretary; and present, also, 235 members and guests, including a number of ladies.

Vice-President Crocker introduced the speaker of the evening, William V. Alford, Assoc. M. Am. Soc. C. E., who delivered an interesting address on "An Engineer's Rambles in Central and South America", illustrating his remarks with numerous lantern slides.

The Secretary announced the following deaths:

STEPHEN PEARSON BROWN, of New York City, elected Associate Member, October 5th, 1904; Member, November 1st, 1910; died December 6th, 1919.

Paul Sourin King, of Wilmington, Del., elected Member, July 3d, 1889; died October 30th, 1919.

William Newbrough, of Kemmerer, Wyo., elected Member, April 6th, 1904; died November 1st, 1919.

Mason Romeyn Strong, elected Member, March 6th, 1901; died December 2d, 1919.

Adjourned.

January 7th, 1919.—The meeting was called to order at 8.30 P. M.; Vice-President Nelson P. Lewis in the chair; Chas. Warren Hunt, Secretary; and present, also, 140 members and guests.

An illustrated lecture by John P. Hogan, M. Am. Soc. C. E., formerly Lt.-Col., General Staff, A. E. F., and Chief of Topographical Service, Second U. S. Army, was presented, on the subject of "Military Maps, with Special Reference to the Application of Aerial Photography to Map Making". The subject was also discussed by Messrs. F. A. Snyder and Allen Hazen.

The Secretary announced the following deaths:

Henry Wilson Hodge, of New York City, elected Junior, January 5th, 1887; Member, October 2d, 1895; died December 21st, 1919.

John Patrick O'Donnell, of London, England, elected Member, July 5th, 1893; died December 2d, 1919.

Robert Van Buren, of Norwalk, Conn., elected Member, June 17th, 1868; died December 16th, 1919.

Adjourned.

FAMILY RELATIONS

Address by William G. Raymond, M. Am. Soc. C. E., at the First Annual Meeting of the Iowa Association of Members of the American Society of Civil Engineers, November 20th, 1919.

It is not clear that the American Society of Civil Engineers and its Local Associations bear the relation of parent and children.

Children look to their parents for guidance and assistance in their affairs until they are able to go alone, and then—well then they usually go alone. Nothing of that sort is contemplated in the creation of local associations of the American Society of Civil Engineers.

Parents usually are anxious to see to it that their children are prepared to go alone, to break away from the family circle and establish new circles of importance and magnitude equal to that of the parent circle. Surely the American Society of Civil Engineers has no wish to train these local associations with a view to having them break away from the central Society, to form wholly independent organizations of importance and magnitude comparable to that of the Society. Indeed, that would be impossible. No such organization could grow into such importance and still be a part of the Society, the part cannot be greater than the whole.

Again, new families are still parts of old families from which they spring until the old families are gone. No one looks for the American Society of Civil Engineers to die.

And so, look for an analogy as one may, it is difficult to see that the relation of child and parent exists between this organization and the great Society of which it is a part.

Therefore, it would seem to be improper to speak of this Iowa Association of Members of the American Society of Civil Engineers and the Parent Society.

This is the day of organization, every one is organizing himself into a society and publishing a magazine. It is not clear that this is a good thing, and so it may be uncertain whether your speaker has to his credit or his debit the making of the motion that created the committee that created this organization.

If the organization proceeds to publish a magazine your speaker will feel pretty sure that a debit should be charged against him. On the other hand, if the Association simply uses its best endeavor to help the greater Society that has made the smaller one possible—and in so doing makes the greater Society of more value to the members of this State—your speaker will feel pretty sure that a credit mark is due. Your speaker did not choose his subject, but did select the title of the

paper, namely, "Family Relations," but upon considering the matter he is fairly well convinced that the title is improper, that there is no such thing as family relationship between this Association and the American Society of Civil Engineers.

The reason for establishing such a local organization as this is found in the hope that by such local organization the Iowa members of the American Society of Civil Engineers will get more out of their membership and by the development of greater interest will contribute more to the progress, influence, and good work of the greater Society than they would or could as individuals.

It is thought that the relationship of the Iowa Association to the Society is not different from the relationship of each individual member to the Society, but the voice of the Association is bigger than the voice of a member, and if the membership is united, harmony is developed out of discord by the tuning of many voices in unison. These voices cannot be tuned together unless they get together in one place.

Except for the stamp of professional competency that goes with the badge, the non-resident member of the Society who does not meet with his fellows more or less frequently, might better subscribe to several technical journals at $5.00 a year each, than to pay $15.00 a year for a dozen issues of the Society's *Proceedings*. The stamp is what is paid for and is worth what it costs if the members make it so.

Now the relationship of this Association to the greater Society—of which the Association is a part—being, as has been said, not different from that of a single member to the greater Society, it remains only to be discovered what the member's relationship is, and do you know, that after thinking over this question for many days, the answer does not come in any elaborate form or apart from a statement of the duties of members to the Society, and the Society to members, and these duties in detail are the subject of another discussion.

Perhaps a general statement may be made without encroaching on another's field.

The duty of a member is to keep himself in all his professional and personal life above reproach, to advance himself as much as possible by study and observation and performance not only as a duty to society, but as a duty to the organization which has given him its stamp of approval as a professional man. The performance of this duty by many members is what makes the stamp of approval worth having. Therefore, if a selfish motive is needed, it is found in the fact that in the performance of duty the member is contributing in a double way to his own advancement.

It is the duty of the Society as a whole to do those things that are necessary to the advancement of the Profession, not simply to make

its members better money getters, but to lift the ideals and professional standards to the highest plane that can be reached. If engineers as a body respect themselves, they will be respected by others. It is the duty of the Society as a whole so to order the practice of the Profession that none but self-respecting men of education and capacity, with hands to do, and minds to reason, and hearts to feel, will be eligible to membership.

It must be remembered always that the great duty of the Profession is to society, and in so far as the individual members forget self and strive for the accomplishment of that which is for the good of their fellows, in so far will the individual realize what should be his ambition. And in so far as the Profession as a whole concerns itself with correct and rational solutions of the great industrial and sanitary problems of society, in so far will it accomplish what should be its mission—the development of a higher and better order of living for mankind.

This Association is part of the greater Society, it is not a child of the Society. It should stand in the relation of adviser for this district to the Society and in the relation of servant too, just as an individual member should stand in the relation of adviser and servant. The difference is only that the Association is more powerful than the member.

The Association by discussion by members may arrive at a clearer notion of proper procedure in a given case than a single member groping by himself may be able to form.

It seems to be very difficult to enlarge more on the relationship of the Association and the Society without encroaching on the subject assigned to another, but perhaps it will be proper to call attention to the belief, which may be disputed, that this Association meeting here should be just as much a meeting of the American Society of Civil Engineers as the little group meeting held every other week in the Society's rooms in New York. True, the officers are not here, but the purpose is here—the function is here, the people are here—and here is a meeting of the Society to which any member is welcome and in the deliberations of which any member may share. The Society is everywhere where a few of its members are gathered together, it is not in New York alone. And this leads to the thought that it may be well to discuss certain evidences of relationship that have been suggested as properly to be created.

The Seattle Association has proposed the creation of certain evidences of relationship, not only to establish the relation more completely, but for the purpose of showing to the world the real National character of the Society, and increasing its influence for good in the solution of questions of National importance with which the Engineering Profession is concerned.

Five proposals were made as follows, amended by substituting the word "association" for the word "section":

First.—That the Annual Meeting be composed of duly elected delegates from the Local Associations.

Second.—That all applications for membership be considered by the Local Association having jurisdiction before being acted on by the Board of Direction.

Third.—That professional papers be first presented to a local association, except those that may be selected for annual meetings or conventions.

Fourth.—That a sufficient proportion of the annual dues be remitted to the Associations to care for the necessary expenses.

Fifth.—That the work of the Headquarters' Office be confined to general administration, issuing the publications, and arranging for annual meetings and conventions.

It is believed that this Association can discuss these proposals with much profit and after due discussion can make a deliverance of the best judgment of the members as to the advisability of pressing these proposals for consideration by the whole Society.

Discussion should proceed, not with any idea of magnifying the importance of this or any local association, but solely with the thought of developing to its utmost the importance and influence of the American Society of Civil Engineers, not simply for the purpose of increasing its power, but for the purpose of making it known as a great organization of high ideals of professional skill and personal and professional honor, and having for its object the advancement of civilization by service to society.

DISCUSSION ON THE REPORT OF THE COMMITTEE ON DEVELOPMENT*

By Messrs. William Hammond Hall, J. P. Hallihan, and J. L. Van Ornum.

William Hammond Hall,† M. Am. Soc. C. E. (by letter)‡—The Committee on Development of the Society by its report of October 14th, 1919, its previous report, and by bringing out the discussion which has appeared in the *Proceedings,* has done a work which should effect much betterment in and for the profession and the Society. But it seems to the writer that the groundwork on which the good of American civil engineers, and hence of their Society, must rest, has not been completely covered even by this excellent committee work and discussion of it; and the writer seeks to draw attention rather to points a little aside from those thus far touched upon.

There is so much good in the Committee's work which will be generally acclaimed, that remarks which might be construed as criticism on some points, can not diminish its value. It is not, on the whole, clear whether the major object of the present movement is the good of the Society, and, incidentally, the betterment of conditions among civil engineers, or the good of American civil engineers, and, incidentally, the betterment of their Society. Very naturally, the good of the Society takes precedence in the Committee's vision; while the betterment of conditions among civil engineers seems to loom largest in the minds of those who have discussed the Committee's work.

Putting the case a little differently: It seems to the writer that, while the Society may attempt much to better the condition of the Profession, it can only succeed in that direction by what civil engineers as men themselves effect before the public. A society of men can not rank with the public much above the individuals who compose it, and a multitude of men who are as a rule individually inert towards an objective, can not expect to be potential in that direction as a body. Special technical accomplishment will of course help the individual, especially when the public sees that as a man he is worthy, but a vast body of men in whom as individuals the public may not, preponderatingly, recognize special merit, can not be helped materially by their representative Society, even though the Society knows them to be each as worthy, technically, as he who has attained to public recognition.

* Continued from October-November-December, 1919, *Proceedings,* p. 920 of Society Affairs.

† San Francisco, Cal.

‡ Received by the Secretary, December 22d, 1919.

Under the heading, "Technical Activities" in the Development Committee's last report, we find the following:

"The Committee believes that the standing of a great engineering society depends mainly on the activity and progress of its technical work, and is of the opinion that more active co-operation in movements for public and professional welfare, as hereinafter proposed, should not be allowed to diminish the importance attached to the technical activities of the American Society of Civil Engineers, but rather that these should be stimulated in the interest of science and the profession."

And then follow suggestions and recommendations, which are excellent. But it seems to the writer that there has been an omission. The reason why "the standing of a great engineering society depends mainly on the activity and progress of its technical work" is because the body of men composing it have not in the past established a firmer and broader footing for it, by placing themselves as citizens further forward, higher up and closer together. Perhaps this has been impossible, but the fact remains that had it been done, the reliance now would not be mainly on the activity and progress of its technical work. And so, it seems to the writer that the report might, to the advantage of the profession, have contained a paragraph substantially like this:

"The Committee believes that the standing of the great Civil Engineering Profession depends more directly on the dignity and forcefulness with which its members conduct themselves as cultivated men and citizens, before the public, and is of the opinion that if, through the more active co-operation in movements for public and professional welfare, as hereinafter proposed, civil engineers succeeded, by exercise of the above qualities and course, as lawyers, doctors, and ministers succeed in this regard, the American Society of Civil Engineers would soon be above dependence on mere technical activities for high public standing."

We do not find such a paragraph in the Committee's report; and yet, does it not state the truth?

Surely, the standing of the great engineering profession before the public—and that is where it lacks standing, and where its members cry out for higher standing—depends on the dignity and forcefulness of its members, individually and as a body, before the public, just exactly as the standing of either of the other professions depends on the like personal and collective deportment, as men, of those who practice such professions.

The public standing and civic influence of the lawyer, as a rule, does not depend on the soundness in law of his briefs or the ability of his arguments at the Bar, much less on his deep erudition in the technicalities of his profession or on his abilities as known to the Bar Association. Attorneys who are most in the public eye, who have very much, if not the most practice, often do not rank very high, technically, with their professional brothers or with the Bench. The very

best lawyers, technically, do not, as a rule, make marked successes before the public. Every old practitioner knows this. The comparatively high standing of attorneys at law can not depend on success at the Bar, for every cause has a wrong as well as a right side, and it follows that lawyers, as a body, are half of the time wrong in their law or their pleadings or in both. What would be said if engineers could be thus indisputably shown to be wrong in half of all their professional judgments and works?

The comparatively high standing of the legal profession before the public is, therefore, not because of the technical accomplishment of its practitioners nor because of the technical activities of the Bar Association, which is the greater society of attorneys at law, but because they collectively constitute a profession which is, under dominance of the Bench, united in upholding professional dignity in the public eye, and this carries with it a mutual respect and forbearance which prevents such underminings of reputation and standing as occur among engineers.

And substantially the same may be said with respect to physicians. The medical profession does not stand high before the public because of "the activity and progress of its technical work" as evidenced by the doings of the great medical societies. But it does stand high because of the "dignity and forcefulness with which its members conduct themselves, as cultivated men and citizens, before the public."

So the public standing of a great society—engineering, or any other—does not, at the base and bottom, depend on its technical activities, except when its truest foundation of strength before men has been sacrificed or never laid by its members. By and large, the public does not care a rap about the technical accomplishment of the members of such a society, or the technical activities of those combined in the society. Look at the high standing and potent influence with the public of societies of men the members of which have no standing based on learned accomplishment or skilled practice, no notable foundation to rest upon, except that of forceful, broad-minded men taking an active and helpful interest in the affairs of men.

In the opinion of the writer, now one of the oldest members of the Society and one who has had much opportunity for observation on the points of this particular subject, John W. Alvord, M. Am. Soc. C. E., put his finger directly on the seat of the Profession's and the Society's troubles when he wrote the following, which I transcribe in order that I may with better understanding, affix a supplement to it, taken from a letter by this writer to a brother member, written in 1915. Mr. Alvord wrote:

"The most of our troubles come from self-centered narrowness, and what the engineer of to-day lacks is breadth of view, less envy and jealousy, and more interest in the business and political world * * *.

We begrudge other people their success. We begrudge the heads of our Society their notoriety, and we tear down other people's reputations in our profession altogether too freely. We should, I think, pay particular attention to those members of our profession who have done good work."

And here I add my supplement:

"Public recognition of high attainment of one engineer, rightly taken, constitutes recognition of worthiness in the whole profession. If you pull the engineer down who has been so acclaimed, you pull the pedestal down with him, and there are no climbing facilities for the rest of us and no high place fit to rest on when we get there. If the young civil engineers could be brought to thoroughly comprehend the vital bearing of this on their futures, there would be a profession established, worth practicing, in about half a generation. As it is—but why picture the situation? You know what it is in this regard, as well as I do."

We can not have a great engineering society on an enduring basis, without a sound professional body on which to rest it. We can not have such a sound body, except we have sound parts, to compose it. In the end, the public will be the judge, and the great body of engineers must present itself for judgment, in language, so to speak, which the public understands and appreciates, and not in terms peculiar to the "shop".

The public will not rank civil engineers high, as a body, if civil engineers do not, in general, show that they recognize and accord worth in those civil engineers with whom the public has become familiar. We can not maintain a presentable appearance as a body, before the world, so long as considerable numbers of the more active part of our body climb out upon the protuberances from the body and saw them off close to the trunk.

Recently, members of the Bar Association of California made a pilgrimage in large numbers to the home of an aged judge, long retired, but formerly prominent as a lawyer and jurist in the State, just to pay their respects to him on the occasion of his birthday. The participants in this pilgrimage were, for the most part, men who had been the youngsters when the judge was on the Supreme Bench, or men admitted to the Bar after his retirement. All were eager to do him honor, though few were acquainted with him, simply because he exemplified high public recognition of the profession, and, notably, had held up the tone of the profession before the public. Such was the talk among the pilgrims. In this case, the Bar Association honored itself, in public estimation, as well as the most worthy jurist. Precedents for the action were cited with pride. Has anything of this character ever happened among engineers? If not, perhaps it has been because no engineer has attained to such standing for a like reason; and, if this be so, maybe it has been because engineers,

in practical ways, have discouraged their fellows from climbing on that kind of a ladder. The public notices such happenings as that lawyers' pilgrimage, to the credit of those participating.

Referring to the Committee's report, under the heading "Membership", if this is a society of civil engineers what is the object of having as a member of any class, under any name, "a person who by scientific or professional attainment has qualified himself in his special pursuit to advise and co-operate with civil engineers in the advancement of professional knowledge and practice"? Such a person may be eminently well qualified as a lawyer, doctor, dentist, veterinarian, chemist, botanist, entomologist, astrologist, archæologist, or other "special pursuit", and may, "by scientific and professional attainment", have fitted himself "to advise and co-operate with civil engineers in the advancement of professional knowledge and practice". But the question naturally arises as to what professional knowledge and practice—that of his own specialty, or that of civil engineering? If the latter, the clause should so state.

But, in all fairness and explicitness, would it not be better to be entirely frank in defining the qualification of those eligible as Fellows, and put the matter as follows:

"Lawyers, doctors, dentists, veterinarians, chemists, botanists, entomologists, astrologists, archæologists, and those following other special pursuits, and who by scientific and professional attainment in their specialties, have qualified themselves to advise and co-operate with civil engineers in the advancement of civil engineering professional knowledge and practice, shall be eligible as Fellows of the American Society of Civil Engineers."

True, this would constitute a good deal of an acknowledgment of weakness and inferiority on the part of civil engineers, but it would have the merit of appearing to be straightforward, bold, and frank, which merit the proposal of the present Committee in the view of the writer, does not have. No one will suppose, of course, that there has been any thought of not being straightforward, bold, and frank, but the intelligent part of the public will not recognize either the immediate or the ultimate object of the clause, will not know whether there is or is not a hidden object.

For instance: The lawyers, doctors, dentists, etc., if they give the matter a moment's attention, will want to know whether they, because of accomplishment in their specialties, are to be considered as qualified to advise and co-operate with civil engineers in the advancement of civil engineering professional knowledge and practice; whether civil engineers, for a precisely similar reason, may not consider themselves qualified to advise with lawyers, doctors, dentists in the advancement of the lawyers', doctors', dentists', professional knowledge and practice? And, if this be not so, the lawyers, doctors, dentists, etc., will question

why that clause in the Constitution of the American Society of Civil Engineers? To get in contributing members? If so, why was not the former definition of Fellow retained, which in simple, direct language said: "Fellows shall be contributors to the permanent funds of the Society, though they may not be eligible for admission as corporate members"? Or, at least some lawyers, veterinarians, and entomologists will think, with pride, that the civil engineers really need their co-operation and advice in the advancement of civil engineering knowledge and practice, and be frank in saying so. Or again: The dentists, botanists, and astrologists may think that the civil engineers are extending to them, in common with the memberships of all other peoples of professional and scientific attainment, an invitation to join, as Fellows, in a crusade for the advancement of professional knowledge and practice of all kinds and descriptions.

Exactly the same question might be raised with respect to "such persons engaged generally in commercial pursuits as possess engineering training and experience qualifying them to be of service to the engineering profession". Why are these affiliates? Does the Society actually need them? And, if so, for what reason? Does it need to absorb into its body all who have color of special ability "to be of service to the engineering profession"? For, if it takes in one person so qualified, it should, in justice and reason, take all; and who can count them in the world, and what would the Society be with them? We can not burden the public mind with all these distinctions between Members, Associate Members, Juniors, Fellows, Associates, and Affiliates. Such degrees and variation in degrees of membership are, to the public, befogging, and, before the public, tend to minimize the value of membership in the American Society of Civil Engineers, of every grade and naming.

The presence on the shelves of the office of the vice-president and general manager of the Nutcracker Manufacturing Company of a file of the *Transactions* of the American Society of Civil Engineers, even though he is a gentleman "of scientific attainment in his special pursuit, qualifying him to advise and co-operate with civil engineers in the advancement of professional knowledge and practice", is befogging to far the greater portion of the intelligent (and wealthy) personages who are privileged to enter there. They know that the general manager is not an engineer, and the fact of his special qualifications to advise engineers has escaped them.

Fellowships and other somewhat similar classes of memberships of societies originated in older countries where and when scientific, artistic and most professional people were poor and dependent on the patronage of people of wealth and high position; and in making such people "fellows", or other non-active members of their societies, they were bidding for patronage, and very rightly they received it.

It was all natural and not to be criticised under such circumstances. The circumstances and conditions are very different in this country, now. A great society such as this Society now is should not seek to draw into its fold any class of people who are not eligible for admission as corporate members, or who do not enter the preparatory or waiting classification of Juniors—except those specially distinguished by accomplishment making them worthy for honorary membership. The example of the great associations of lawyers, the great societies of the medical profession, should prompt civil engineers not to cheapen their National organizations through reaching out for those who can not be regarded other than as patrons.

Is it a fact that the "so-ness" of the technical engineer's lines of thought prevents him from seeing how differently many things pertaining to his profession may strike people not of it? It has sometimes seemed to the writer, when he has painstakingly "climbed over the mountain to get the view there", that, even though he saw only "the other side of the mountain" he was amply repaid for his labor, by realizing that in all things very much depends on the viewpoint—the other fellow's viewpoint. If civil engineers, as individuals, will climb over the great obstruction which blocks their advance as a body, and join the crowd looking at the other side of it, though they there see only "the other side of the mountain", they will generally discover that, by being more of psychologists with respect to the public mind and less of technicians with regard to their own, they can locate, construct and operate lines for advancement on easy gradients and without excess curvature, either over or around the obstruction against which they have butted for several generations.

But, so far from clearing the way for general advancement of the engineering profession before the public, there are now rampant certain special influences pertaining to engineering practice which are constantly operating to heap higher the obstructions.

Why are municipal boards of public works not composed, predominantly, at least, of civil engineers? City public works are eminently civil engineering works, and the authorities charged with them should in the public and the taxpayers' interest be composed of civil engineers, just as boards of health are made up of doctors of medicine. If an appointing power named to a board of health a hotel keeper, merchant, or lawyer, the medical profession would protest in formal array, and foremost in the fight against the appointment would be the physicians in charge of the hospitals under the health board, with the plea that their efficiency necessitated supervision by their profession, exclusively. Not so with civil engineers. A city engineer, as a rule, privately if not openly, resents the appointment of another civil engineer to the board of works whose technical expert and executive he is and, apparently, for the reason that he does not want another civil engineer

to be in position to act as a check upon him. This attitude is destructive of the public standing of the profession.

True, men are named to boards of public works chiefly because of political or other influence, to the exclusion of special fitness; but this is because there is no due and competent representation before the public and the appointing power of the fact that civil engineers are the specially competent citizens who, in the public and the taxpayers' interest, should be selected for such duties; and because very many civil engineers discourage members of their profession from putting themselves forward for such preferments, and take occasion, privately, to say that the individual who does it is not much of an engineer, anyhow.

Another point: Great municipal public works, whose cost runs into many millions, are designed and carried out by city engineers without retaining any other engineer in consultation. As a rule, so far as the writer has observed, the city engineer fights off the consulting engineer proposition, as constituting a reflection upon his abilities, or he tries to have his personal friends selected for the consulting service. This is all wrong and damns the profession.

The executive engineer in charge of public works should welcome proposals for consultation, exactly as the doctor of medicine and the surgeon does, only taking care that reputable and able, and not disreputable or weak, consultants be chosen. That is a most potent way to build up the profession and to strengthen and even to save individual reputations. When a law case bids fair to become important or to be tenaciously fought, the original attorneys quickly strengthen their respective sides by bringing in counsel—the strongest they can induce their clients to pay for. When a medical or surgical case develops indications of a serious character, the physician or the surgeon promptly recommends the calling of a diagnostician, a consultant, or a specialist, and his advice prevails.

City attorneys often insist on employing special counsel on the city's more important cases, and see that they are mighty well paid and retained as long as there is need for them. City engineers, as a rule, stave off employment of consultants or engineering specialists even on their most important works, load their pay-rolls with comparatively small and unknown men who bring to them, perhaps, much university acquired technical knowledge, but little of the wisdom of actual experience or observation of experience and who naturally, before the public, can not uphold them and establish public confidence. When an engineer holds a prominent public post, with important design or construction in charge, it is a most important duty to see, through professional and not political support, that he is understood and upheld by the public —his employer. If he will look back and see how many of his fellows have run on rocks and been wrecked, and have dragged down their local professionals with them, by over self-confidence and grasping jealousy,

he will, almost certainly, if there are "no strings on him", call in others to help him, and not merely take his orders.

But perhaps the worst sin, in the line of professional practice, of which civil engineers are often guilty, to their profession's grave injury, is that of secrecy with respect to their works. An employer is of course entitled to privacy for his business, but, even as to such works, a vast and helpful fund of experiences passes on into oblivion each year, which civil engineers would be at entire liberty to formulate and record for the benefit of their profession. While, with respect to public utility works and distinctly public works, the vast sea of nothingness is receiving the run-off of engineering experiences in about the same proportion the seven seas of earth are made catch-alls for the drainage from the continents and islands. The engineers in charge seem to be satisfied to let it go so. The Profession is kept poor in the wisdom which comes with experience, as well as poor in that public recognition which a right exposition of such wisdom would bring.

A specially noxious guilt of this character is to be laid at the doors of many city engineers. They are employed by the local public, and their employers are entitled to prompt and useful accountings for the moneys expended by their plans and under their supervision; and, moreover, the public is entitled to have the instructive technical and practical experiences which follow construction of works, so formulated that the civil engineering profession may to best advantage serve it in the future. But city engineers, all too often, render no such accounting. On the contrary, they seem to look upon the most valuable lessons of their works as a sort of private property; the public becomes impatient, the engineers are suspected and abused, and the profession is incidentally, but decisively, "queered" in the public mind and woefully weakened in the estimation of those most likely to be employers of engineers.

Every law case that goes through the Courts is as an open book to the legal profession; and the Court in its decision tells the right and wrong of it. On such knowledge the profession of the law, in this country, is for the most part built, while its battles and their lessons are in the open. And just so, in a very large degree, is it with medicine and surgery—the hospitals and the medical or surgical colleges and societies gather in the larger and more important parts of the practitioners' experiences, from individuals and through boards of health, and promptly put it before the profession. The literature of the law is voluminous and well systemized, not only in the official Court reports, but in many specialized textbooks. In a lesser degree, perhaps, the literature of medicine and surgery is systemized, detailed, and thorough. By comparison, the reports and digests or special treatises on civil engineering experiences are meager, unsystemized and anything but thorough. A profession must rest, not only on the principles of its

basic science, but on digested records of practice—experiences in the application of those principles. In this regard the civil engineer is woefully handicapped. Whose fault is it?

It is not because of shortage in technical learning that the profession suffers, but from what Mr. Alvord called—"self centered narrowness", and this is exemplified not alone by certain kinds of conduct toward each other, but by practitioners hoarding the results of their experiences for no practical purposes whatever. He who would more fully realize this should run through *Transactions* with a list of the members before him, and see what records most of the men of largest practice have made for themselves. As for the military engineers: Think of the millions on millions of money spent under their direction, on river and harbor works, with practically no digested reports of technical or practical outcome, no treatises, no useful accounts which are really available for the libraries of members of the profession, or, in an easily practical way, even in great public libraries.

Concealment of public works experience and results is sometimes excused on grounds of public policy. In such matters, how can it be good policy to keep from the public knowledge which it has paid for? If it be encouraging, the public should be buoyed up by it; if discouraging, the taxpayers should be privileged to face and make the best of it at once. It is only through concealment and delay that real injury can be inflicted on a great public in such matters. And it is by such concealment and delay that engineers not only ruin themselves, but undermine their profession in public estimation.

There is just now, more than ever, operative another potent influence on the public mind, through what is growing to be a custom in engineering practice, to the serious detriment of American civil engineers and their profession. The profession is worth practicing only so far as the public and employing class of the people think it is worth employing and paying. Anything coming from engineers themselves which directly, explicitly or by comparison, tends to depress the standing of the civil engineer in public estimation, constitutes a distinct injury to the profession. For some years past and, as this writer observes in many instances now, university professors have been and are seeking and obtaining much practice as civil engineers, and holding commissions or appointments, carrying good salaries, from States, cities and other public as well as private or corporate bodies, and even from bureaus of the general Government, while yet retaining positions and emoluments in the faculties of their universities.

These able gentlemen are not known to the public as civil engineers, but as "Professors". This large, round, and learned-like word carries a pregnant meaning to most people, and even very intelligent and influential men of the classes who constantly employ engineers are coming to look upon these "Professors" as some sort of super-engi-

neers by some mysterious process, especially experienced as well as particularly learned. There seems to be an impression growing that results of all engineering experiences are promptly gathered into the universities, and there correlated or digested, and only there is the ripest scientific engineering advice to be had, and service secured.

The writer has been at no little trouble to look into this subject and, having been for years past out of engineering practice, can not be thought to have personal motive when he declares that in his opinion, based on special and somewhat wide inquiry, these "Professor" civil engineers are doing their brother engineers and their profession a very great injury. He knows that among groups of men with money for development works, and men who are directors of operative companies, and among members of legislatures, there are always those who bring forward the "Professor" as the man to be employed or consulted, in preference to the plain civil engineer—apparently for the sole reason that he is a university professor and, presumably, is superior to the man who is not. The writer has even known it to be urged that a "Professor" be employed because, by reason of his university pay and facilities, he could and would do a cheaper as well as a better job.

The "Professor" in his capacity of professor of civil engineering or some related chair in the university, sends out into the professional world each year, several dozen or more graduates from his classes. These young engineers look to him for advice and help, which they usually get, free, and if there is a chance to bring in a consulting engineer on business they can secure or influence, the "Professor" gets the fee; and he not infrequently is willing to take a small one, in order to get the business, on the plea that he thereby secures experience and data which is valuable to bring before his classes, and his classes may learn something practical by helping him. Such talk is widely current among civil engineers, and the writer has good reason to believe that it is well founded.

There naturally ensues, of course, an idea on the part of university governing bodies that salaries of \$3 000 to \$4 000 or \$5 000 per year are sufficient for professors of engineering, because they can acquire as much more by private practice or public employments outside of the university and, as above explained, with advantage to their class men and the university service. It follows that professors may be encouraged in this practice. It certainly does follow that young university-made engineers do not seem to be started into professional life with that respect and deference for those who have built up, by hard work and hard knocks suffered, all there is of it, which is absolutely essential to the unity, concord and team work necessary to uphold the profession before the public. Surely the young engineers can not expect to take precedence. The public never heard of them. There is a new batch coming out every year.

This condition largely results from the fact that university professors of engineering are, in so many notable cases, practitioners of the profession, before the public, and, instead of bringing into their class rooms the notably experienced men of the active profession, to lecture or informally tell of works and the lessons of practice—thus at once recognizing merit in the established profession, and laying the foundation for unity and good understanding between its active members, old and young—they, no doubt without premeditation, undermine and do much to render barren the very field of endeavor they are qualifying their youngsters to work in. If civil engineers would persistently work as a body before legislative, executive, and directing authorities, and finally correct this abuse, they would thereby make a long stride toward better permanent conditions for their profession—a stride which, with several others of like character, is, in the opinion of the writer, absolutely necessary for the attainment of the goal.

The course would be to see that professors of engineering are sufficiently well paid to render wholly unnecessary their having any other source of income. This would set a higher standard of pay for first-class engineering service, would keep the professors out of the civil practice field, and should not be so much of a burden on the universities because, if a professor devotes all of his time to his university work, manifestly he should require somewhat less expensive assistance.

This writer has heard a member of a university governing body state that, while it certainly was most desirable to pay professors, in general, full living salaries, it was not so with respect to professors of engineering, because they could get other revenue by practicing their calling before the public, and could bring the business into their class rooms to the great benefit of their undergraduates. How is it possible to uphold the civil engineering profession before the public in the face of such ideas in the minds of those who most directly control the situation, and which ideas seem to go, year after year, uncontroverted by the engineering organizations which might correct them.

When the Mayor of a city, the Governor of a State, the President of the United States or any of his cabinet or bureau officers reaches out into university faculties for professors to employ or commission to carry out engineering works, investigations or developments provided for by law, he gives notice either of his ignorance of this situation—which is altogether natural, under the circumstances—or of his willingness to take advantage of it and have the fact proclaimed to the public as a thing greatly to his credit, that he has secured the superior services of Professor So-and-So of the University of Blank, for the important work. That he has snubbed the active practitioners of the engineering profession, deprived them and the profession of a measure of support to which they are entitled and, practically, said to the world either that

they are not professionally able, or personally unworthy of his consideration, never seems to enter his brain.

Who is to blame for all this? Primarily, not the Mayors, nor the Governors, nor the Presidents, nor the cabinet officers, who do the appointing, but the body of civil engineers, who, through inaction, allow such misunderstandings to continue.

Quite a number of years ago, in a certain locality on the Pacific Coast, it became common to employ a crack military band to render the music at civic functions, and even at some of the larger private assemblages. The local band musicians' organization took action, and through the influence of a Congressman the practice was promptly stopped, on orders from Washington. At a still earlier period, Army doctors or surgeons were practicing medicine largely among civilians in the neighborhood of their posts on the Pacific Slope. Local physicians brought the matter before State medical societies, and these carried it to the proper authorities in Washington; and, again, this abuse was stopped. For many years it was the practice of ranking members of the U. S. Engineer Corps, stationed at San Francisco, while still on active duty, to practice the profession in civil life, and they were getting much of the cream of the business. One civil engineer, who himself was well provided with work, in the interest of fellow engineers less fortunate, started a movement to have the military engineers kept within the traces which the Army regulations contained. A number of other engineers joined him, but very soon backed down, and several of them actually joined forces with the enemy, so to speak. The practice went on, until the personnel of the engineers was about all changed; but the civil engineer told the story, as a joke on himself, in Washington—how he was dumped into the ditch by those he had tried to help. The then Chief of Engineers heard of the incident, enquired for particulars, and later sent for the civil engineer and showed him a copy of a circular letter he had sent out, calling attention to the regulation which prohibited Army engineers from taking any outside business, except on special permission and approval for each case.

In all such matters, it is not the money that is directly lost to the civilian practitioner, and gained by the Army engineer or the professor-engineer, which most counts. It is the moral effect on the public mind, to the prejudice of the civil engineering body. The glamour of the military band was what put the civilian band in the shade, and not the superiority of the music made by it; the consequent implanting of the idea that civilian bands were inferior to military bands, constituted the real damage and justified the uproar that was made about the matter. And so it was the dark-blue undress uniform with the military insignia, worn by the Army surgeons in those days, taken with the titles—Colonel, Major, or Captain—by which they were addressed, that eclipsed the civilian doctors, and not any greater suc-

cess in medical practice by the Army men; and it was the implied inferiority of the civilian doctors which unavoidably ensued that justified their protesting.

In the same way it is the belittling of the civil engineer before the public and with employers of engineers that inevitably follows upon Army engineers in active service, and "Professor" engineers in great universities, practicing in the civil engineering field, which does the injury. It is not the money which civil engineers fail to receive, and which "Professor" engineers and military engineers do get; it is the false ideas with which the public and many employers are inoculated and which become cultures in their minds that operate to keep the civil engineer on a comparatively low plane as a professional man.

One only has to be a thoughtful observer of the manners of men amongst men to note the significant difference between the receptions accorded a Colonel of the Engineers, U. S. A., and any local civil engineer of first rank in his profession, before a Chamber of Commerce; or the equally significant difference between the estimation in which a "Professor" engineer and an unadorned civil engineer is held by a committee of the Legislature; and the difference in space accorded to the Colonel and the "Professor", as compared to that given the plain civil engineer, in news columns. These phenomena are to be observed in full display well west of the Atlantic seaboard. The civil engineer who does not realize their deep significance, as affecting his civic standing and his earning capacity, is deficient as a student of the psychology of the crowd.

And still again: It has come to pass that the United States Reclamation Service bureau is looked to by about all of arid America to supply the engineering skill and brains necessary to effect water conservation, irrigation, and flood prevention in that vast region, whether the works are to be paid for by Government, State, or private funds; and, consequently, what should be a great field of engineering activity, worked by men of ripe experience, scarcely exists for independent practicing civil engineers.

That Governmental action in water conservation and irrigation of public arid lands, as well as in flood prevention and in investigating the broad physical problems of the arid region for public information and benefit, is right and necessary, goes without saying. The writer had the honor of being the first engineer in America to start systematic work and propaganda to these ends. As the first State Engineer of California, he conducted one of the two first State irrigation investigations; and as the first civil engineer called by the Director of the U. S. Geological Survey, he later organized, and conducted for all the region west of the Rocky Mountains, the first U. S. Irrigation Investigation out of which the Reclamation Service has since grown.

Thus, the writer was the first to promote and, later, to do practical official public work or service of this character, in a large way, in this country. But when he realizes the extent to which bureaucratic action in these matters is being carried, to the extinguishment, apparently, of the civil engineer in connection with large arid region developments, except as he is an employee of the Governmental bureau, the writer feels that the matter ought to be brought into this discussion for the good of the profession. This tendency simply raises the question whether the civil engineer is or is not to continue existence as a general professional practitioner of any importance whatever, in a large part of this country.

Just where the line limiting bureaucratic engineering should be drawn, and where the civil engineer may begin as a practitioner in a large way, is perhaps difficult to say; but that line, in the opinion of this writer, should not be where, apparently, it is now. Nor should the bureau engineers be embarrassed by having the task of drawing the line placed solely upon them. They must, necessarily, be embarrassed by political, local and private insistence, and thus need help. Therefore, if the task assigned to the Committee on Development covers the subject of the good of the Profession as well as the good of the Society, the relation between bureaucratic engineering and civil engineering should assuredly be dealt with. Within a few years it will be of overshadowing importance.

All such Governmental and State bureaus should work to build up and to strengthen in every way, and not to supplant, the profession in civil life which they represent in official life. Have they done this? Do they do it? Will they do it? If these questions are not to be answered positively in the affirmative, then here is another influence against which the civil engineering profession can not possibly stand without strenuous and decisive action.

If the principal and greater part of the lessons of civil engineering practice in several of the largest fields for civil engineering expansion are to be gathered promptly into Government bureaus and universities and thence by bureau and university engineers put into use afield, after the apparent manner of the present, it can not be possible that civil engineering, as a free profession, can attain to and hold a high place.

The people are coming to look to Government and the universities for civil engineering guidance and service. These fields, under the influence of "pull", will be gradually extended. The engineer, in the eyes of the public, will be just what he appears to be within the bureaucratic or the university setting—a more or less cheap employee, without personal business ambition or the possibility of advancement, except by permit or favor from above, or death or disability of his ranking engineers. The value of the outside engineer will be gauged by the

apparent value of the inside engineer, as fixed by Government or university. The fact that he is on the inside, practically has almost a life position, will be overlooked, and so the free civil engineer will be able to earn for each of six to eight months of the year at the rate per month that the bureau or the university engineer receives for each of twelve months.

The only apparent preventive for this sort of outcome seems to be a united stand, on the part of American engineers in general, and a demand that the technical professions shall be respected, upheld, and fostered, by university and Governmental authorities—city, State, and Federal—rather than undermined, as now. Engineers should take cognizance of the different treatment accorded lawyers and study the reasons for it, and should look well to the movements for self-protection which are in progress all around them.

It may be said that the foregoing constitutes a narrow view of our problem, that civil engineers should rise above such considerations and triumph over such embarassments. This sort of argument has been advanced, to the writer's personal knowledge, for near half a century; meanwhile, civil engineers have had all the opportunity that there could be to rise and to triumph. But by their present showing and what has been called "unrest", they acknowledge failure, while other professions and callings of professional character, by heeding precisely such precepts as are herein written, have made comparative successes before the public, and are not, as professions or learned callings, giving evidence of defeat in the race of life, as are engineers.

Those comparatively few civil engineers who have attained to what may be called the "Professor" engineer grade, in the estimation of great employers and before the public, and others prominent in the specialties of railroad engineering, and the like, or in the employ of great corporations or construction companies, wherefrom the "Professor", the Military, and the Bureau engineers are, by circumstances, debarred, may not see force in the points which the writer tries to present. But the general practitioner in middle life and past, if he is at all a student of human nature, will see much to heed in them; and when he has spent years in retirement—so to speak, "on the other side of the mountain"—he will probably agree with the writer's views, heartily.

For the good of the profession, and consequent strengthening of the American Society of Civil Engineers, look first to the points which affect the profession's standing with the public, as these points are seen with the eyes of the public.

J. P. Hallihan,* M. Am. Soc. C. E. (by letter).†—The report of the Committee on Development indicates that the majority of the members of the Committee, and (as the non-resident members of the Committee

* New York City.

† Received by the Secretary, December 12th, 1919.

were in the majority) a majority of the non-resident members of the Society, are in favor of an extension of the activities of the Society to the end that it may wield a direct influence in civic, State, and National affairs.

As understood by the writer, it is proposed to accomplish this result by an extension of the principle of the Engineering Council, composed of representatives of the four Founder Societies, to all local associations of engineers, constituting in effect, District Committees of the Council.

The writer is in entire sympathy with this plan and has no doubt that it can ultimately be worked out in a satisfactory manner. He believes that any plan that brings the members of the various branches of engineering closer together, that promotes greater interchange of thought and in particular a wider personal acquaintance, will greatly benefit the profession as a whole. Particularly is he impressed with the proposal to convert the lower floor of the Engineering Societies Building into a reading room and club room, where a visiting member or guest may be made to feel at home.

However, in carrying out these clearly sensible ideas, why is it necessary to disturb the technical activities of the Society by discontinuing the semi-monthly meetings at the National Headquarters in New York, and as well the preparation and publication of the *Proceedings?* The membership of the Society now totals more than 9 000, of which over three-fourths are non-resident. The only means these members have of keeping in touch with the affairs of the Society is through the medium of the *Proceedings*, which reaches them once a month. Few of these may be contributors, either in the form of original papers or in discussion, but the large majority are careful readers of both papers and discussions, and apply in their work the principles of engineering in accord with the best thought and methods developed in the forum of the National Headquarters.

It would appear unwise to change this situation until it is certain that something better can be offered. It is suggested that papers be presented for discussion to the local sections and that those of importance warranting publication be published in *Transactions* at the end of the year. This plan would restrict the audience to the local section until the publication of the *Transactions,* and would correspondingly reduce the value and interest of the discussions. In this connection it may be noted that *Proceedings,* being of a convenient size, is carried about on journeys and read. *Transactions* goes into the library as a reference book.

It is doubtful if many of the local sections will see their way clear to financing the publication of papers and discussions. Their membership is limited, no greater percentage of it is active than is the case with the National organization, and the majority of the non-resident members of the Society do not belong to local associations. Particularly

is this true of members employed in foreign work, whose number may reasonably be expected to increase if American bankers follow the British policy of looking after their foreign investments.

It would seem to be much safer to retain the present method of technical activity, extending it, however, to permit the presentation of papers to the local section simultaneously with their offering to the Board of Direction.

On the other hand, the extension of social features, of greater fraternization among the members of the various branches of the profession to the end that they may speak with a united voice in civic affairs, is of such far-reaching importance that it merits being taken up as a separate activity. By itself, as a movement for the general welfare of engineers, it would speedily justify all the help the Society could offer, and a reasonable increase in dues of all members for this specific purpose on a definite programme of action would no doubt meet with general approval.

J. L. Van Ornum,* M. Am. Soc. C. E. (by letter).†—The report of the Committee on Development seems to the writer to be so admirable in its general provisions that only the best of reasons would justify dissent from any of its conclusions. His conception of the purpose of student societies and his personal experience with their functionings, however, constrain him to protest against the adoption of the section, B-4, entitled "Student Societies", of the report of that Committee.

If the object of student societies was mainly that of hearing addresses, the writer would heartily favor the recommendation; but he is very sure that this benefit constitutes only a subordinate portion of the field of service that such a society offers to the engineering student, when it is properly organized. A student society, instead of being constituted mainly for the purpose of giving its members the opportunity to learn passively what they may from addresses, etc., may and should serve to supplement the courses of instruction in a much broader and more effective way by particularly encouraging their initiative, judgment, and realization of personal responsibility for their own preparation for their profession. A few illustrations will render this conception more definite.

One important part of the experiences of an undergraduate should be his personal co-ordinating of the class-room training with practical engineering work. This is difficult to accomplish. In a few schools of engineering it is done by establishing alternating short periods of school and shop. In a majority, the only recourse is for the student to engage in engineering work during his summer vacation. It is not easy, generally, to induce undergraduates diligently to adopt this

* St. Louis, Mo.

† Received by the Secretary, December 17th, 1919.

system; but when the student society itself systematically arranges the programme of a portion of its meetings to hear reports from its own members on their summer's work, and then to discuss and criticize them, there results an appreciation of the value and importance of utilizing in this way all their available time that is very real, because it is evolved from their own growing perception of its indispensability.

Another need is that students should have training in speaking, so that they may present their conclusions and convictions convincingly. The writer believes that this, also, requires the student's own recognition of its importance in discipline. In many engineering schools argumentation has no place in the curriculum. In addition to the incitement toward this object by the procedure outlined in the preceding paragraph, the setting apart (periodically) of other meetings of the student society to hear and discuss reports, made by designated members on selected articles in engineering periodicals, will give additional opportunity for this kind of training.

A third need, which requires all the encouragement possible, is that students should grow to realize the importance of constant contact with publications "in order to secure a large fund of facts with which to reason effectively", etc. The plan mentioned in the last paragraph greatly aids in developing this habit.

These three examples illustrate a few of the ways in which untrammeled student societies do definitely supplement the class work of the schools in a very advantageous way. The essential feature of it all is that its vitality and effectiveness depend on the student's own progressive discernment of his needs and the consequent encouragement of individual resourcefulness to supply those needs. This fundamental advantage is taken from him unless a majority of the meetings are of such a nature that he is given the opportunity to develop his own powers, largely by his own efforts. Certainly, the present aspect of engineering education displays more opportunity for giving the student information from above than it does in encouraging the very significant function of self-discipline.

If student societies ought to have the chance to develop along the lines indicated, they must be differentiated among the various branches of civil, electrical, mechanical, mining, chemical engineering, etc. Otherwise the student's interests and enthusiasm will be dissipated over so broad a field that they will become so very tenuous that comparative impotence will result. If mature men have proved, by experience, the wisdom of having both National and local engineering societies divided among the principal branches, how much greater is the need of a similar differentiation for student societies the members of which are yet immature in all those qualities that are essential to prevent "breadth" degenerating into superficiality or dilettanteism.

The writer greatly hopes that the Society will substitute a plan favoring student societies in each of the principal branches of engineering with provision for joint meetings, at intervals, to hear addresses and other purposes where concerted action is desirable. This character of organization would be similar to that of the National Societies, having their individual activities, with Engineering Council (or the National Engineering Organization proposed in the same report of the Committee on Development) to represent those interests common to all. Incidentally, such action would bring into harmony the provisions of Section 4 of page 8 with the purport of Section 5 of page 17 of that report (especially as elucidated in the last two lines).

ITEMS OF INTEREST

The Committee on Publications will be glad to receive communications of general interest to the Society, and will consider them for publication in *Proceedings* in "Items of Interest". This is intended to cover letters or suggestions from our membership covering matters which are not of a technical character. Such communications, however, must not be controversial or commercial.

NATIONAL SERVICE COMMITTEE OF ENGINEERING COUNCIL

In response to frequent expressions of need, Engineering Council announces the establishment of a National Legislative and Departmental Information Service for engineers in all branches of the Profession. Information relative to engineering statistics, research, and construction, as well as of matters before Congress involving engineering considerations, will be furnished without charge by addressing the National Service Committee, M. O. Leighton, Chairman, 502 McLachlen Building, Washington, D. C. The National Service Committee also announces that its office at Washington is open to members of the Society at all times, and that accommodations can be had there at short notice for committee meetings of the Society, or of any organization in which the Society is interested, which may be held in Washington.

ACTIVITIES OF ENGINEERING COUNCIL

Registration of Engineers

Because of widespread and persistent interest in the subject of licensing or registering engineers, architects and surveyors, Engineering Council, at its meeting of October 25th, 1918, authorized the creation of a committee to make a thorough study and submit a report. Fifteen engineers from all parts of the country and of long experience in the various branches of the profession of engineering were appointed as members of this committee, as follows: T. L. Condron, Chairman, Francis C. Shenehon, Farley Gannett, John H. Dunlap, Caleb M. Saville, A. Lincoln Fellows, C. H. Snyder, Bion J. Arnold, John W. Alvord, and J. W. Woermann, of the Society, and A. M. Schoen, Arthur M. Greene, Jr., James H. Herron, John Klorer, and Amos Slater.

After much hard work extending through fourteen months, the committee presented a report to Engineering Council at its meeting December 18th, 1919. This report is accompanied by a "Recommended Uniform Registration Law, to regulate the practice of professional engineering, architecture and land surveying". Council voted to receive this report and to give it immediately, together with the pro-

posed law, as wide publicity as could be secured with the aid of the engineering and architectural societies and the technical journals, in order that the members of these professions might be informed and discussion elicited to guide Council in the consideration of this important matter at its meeting in February, 1920. Engineering Council has as yet taken no action upon the merits of the question of the advisability of legislation providing for the registering or licensing of practitioners of the professions named.

Report by Committee on Licensing Engineers, December, 1919

During the past fourteen months, this committee has had under consideration and study the subject of the licensing or registration of engineers. The fifteen members of the committee, as appointed by Council, were selected from thirteen States, *viz.,* Connecticut, New York, Pennsylvania, Ohio, Georgia, Louisiana, Illinois, Missouri, Iowa, Minnesota, Colorado, California, and Washington, and therefore represent practically all sections of the United States, as well as mechanical, electrical, mining, hydraulic, municipal, sanitary, railway and structural engineering, and also colleges of engineering.

The first work of the committee was to investigate the general subject and to collect, so far as possible, available material bearing upon the subject in hand, including opinions from many engineers as to the need or desirability of legislation, as well as copies of all State laws passed and proposed, having to do with licensing or registration of engineers, architects and surveyors.

This preliminary investigation disclosed that very pronounced views were held by engineers throughout the country, both for and against State licensing or registration. The general sentiment one year ago was more opposed to such measures than it is to-day. The older members of the profession did not, as a rule, favor licensing nor did they feel there was need for State regulation of engineering practice, while among the younger men there was a feeling that licensing or registration by the States would add prestige to professional engineers and in many ways benefit the profession, as well as individual engineers.

The advantages claimed for State licensing or registration are the same as those presumably gained by the laws regulating the professions of law and medicine, namely, that those who are incompetent and unqualified professionally to practice are unable to obtain certificates or licenses and hence both the public and the profession are protected. On the other hand, those engineers who have already attained to recognized professional standing feel that they not only do not need the benefits claimed for such legislation, but they fear that State licenses or certificates of registration are apt to put the seal of State endorse-

ment on men who do not deserve it and that the public would assume that a licensed or registered engineer was thereby certified by the State as fully qualified, regardless of what might or might not be the requirements demanded before a license or certificate was granted.

However, the question has gone beyond the stage of debate, for already nine States* have enacted laws licensing or registering engineers, and other States are certain to enact similar laws during the present or coming sessions of their Legislatures. In addition to these nine laws governing engineering practice, there are at least six States that require the licensing or registration of land surveyors and in at least eighteen States† laws have been passed licensing or registering architects. Some of the nine laws are so drawn as to include both engineers and surveyors and some include engineers and architects and one or two include engineers, architects and surveyors. Moreover, these laws are not at all uniform, and in several instances are likely to prove seriously embarrassing and annoying to engineers whose activities extend beyond the limits of a single State. Because of the nature of professional engineering work, the practice of an engineer frequently extends over several States and therefore it is vitally important if there are to be State regulations for engineering practice, that these regulations be made uniform so far as possible and that the Engineering Profession unite in wisely directing such legislation.

As stated, laws have been passed in seventeen States for licensing or registering architects and the American Institute of Architects has endorsed and advocated such legislation, considering that both the architects and the general public are benefited thereby. Unfortunately, some of the laws for licensing architects have been so drawn as seriously to interfere with legitimate engineering practice and the "model law" proposed and advocated by the American Institute of Architects contains definitions of "architecture" and "building" which, should such laws be passed and enforced, would prevent any one but a "registered architect" from planning or supervising the construction of any structure or any of the appurtenances thereto; consequently under this head would come a structure having simply foundations and girders, whether "with or without appurtenances". Under this model law, proposed by the American Institute of Architects no one but a registered architect shall prepare plans for or supervise the construction of a building, and a "building" is thus defined in Section 19:

> "A building is any structure consisting of foundations, floors, walls, columns, girders, and roof, or a combination of any number of these parts, with or without other parts or appurtenances."

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* Colorado, Florida, Idaho, Illinois, Iowa, Louisiana, Michigan, Oregon, and Wyoming.

† California, Colorado, Florida, Idaho, Illinois, Louisiana, Michigan, Montana, New Jersey, New York, North Carolina, North Dakota, Oregon, Pennsylvania, South Carolina, Utah, Washington, and Wisconsin.

Since none but a registered architect shall have the right to design or supervise the construction of any structure, or any appurtenance thereto, this matter becomes of vital importance to mechanical, electrical, sanitary and mining engineers, as well as to structural engineers.

In the State of Illinois a similar law for licensing architects was passed several years ago, the rigid enforcement of which made it necessary for engineers to unite in having a "structural engineers' license law" passed by the Legislature, and now there are two laws in force in Illinois, one for architects and the other for structural engineers.

In some States, the laws enacted and proposed are intended to regulate the practice of architecture, while in the other States laws have been enacted the purpose of which is simply to protect the term "architect", but not intended to regulate the practice of architecture. In Wisconsin and several other States no one may use the title "architect" without first obtaining from the State a certificate of registration as a "registered architect", but any one not an architect may prepare plans and supervise construction provided he does not style himself an "architect".

Therefore this committee at its meeting of October 13th, 1919, adopted the following resolution, which was carried unanimously.

"Motion: The following is the sense of this committee relative to the desirability of a law licensing or registering engineers:

"Resolved: The enactment of legislation to provide for the registration of professional engineers is desirable and necessary. Ten* States have already enacted such legislation. Laws licensing architects have been enacted in several States and similar laws endorsed by the American Institute of Architects, are pending in several other States, which, if enacted, would prohibit engineers from continuing their customary and recognized practice."

This committee has made a very careful study of definitions for "engineer", "engineering", "architect" and "architecture", but it was found that any definitions for engineering would be so general as to include too much, or too specific to be sufficiently general, or too voluminous to be suitable to incorporate in a law. Some have endeavored to include in a definition of "engineering practice" all sorts and kinds of construction work, but engineering includes investigations as well as plans and no catalogue can well be prepared sufficiently detailed to include all sorts of engineering activities. Several definitions are included in the appendix to this report, and it will be seen that both engineering and architecture are broad terms involving construction and necessarily there can be no sharply drawn distinction. Architects in the broadest sense are engineers even if usually architecture is associated with ideas of artistic or decorative features. Architects are

* Upon later information, this is reduced to nine.

eligible to membership in the American Society of Civil Engineers and several architects are members.

The only basis on which the practice of any profession may be subject legally to State regulation is "in order to safeguard life, health and property". The State may not dictate that any one without a particular kind of artistic talent or without a tenor voice may practice engineering or architecture, but it may legally require that no one shall practice architecture or engineering who is ignorant of the effects of loads and applied forces or incapable of determining the stresses in structures due to loads and applied forces and unable properly to proportion materials in structures safely to sustain such loads and forces.

Land surveying does not involve matters that would ordinarily jeopardize life and health, but property rights are vitally affected by land surveying, and many States have deemed it essential to place restrictions and safeguards about the practice of land surveying. Land surveying is associated with both engineering and architectural practice.

This committee has therefore deemed it advisable and to the best interests of all concerned to include in one law provisions for the registration of engineers, architects and land surveyors. It has recognized that the practices of engineering and architecture overlap in many instances, especially in connection with the larger projects of modern structures, where many branches of the arts and sciences are combined, involving architecture, structural, mechanical, electrical, sanitary, and other lines of engineering.

There are ample reasons why architects alone should judge as to the qualifications of those desiring to practice architecture and why engineers alone should pass upon the qualifications of those desiring to practice engineering. Hence a bill for legislation has been drafted by the committee along these lines and it is confidently hoped that the objections expressed by the American Institute of Architects against laws which might provide jointly for the registration of engineers and architects will be overcome by the terms of the bill herewith submitted.

In fixing the qualifications for registration in the proposed bill, these have been purposely made high, but they have not been made unnecessarily difficult for reasonably competent men to meet. It is not intended that candidates would ordinarily be subjected to written examinations, but rather that the board of registration would pass upon the sufficiency of the professional record of each candidate. Minimum qualifications have been clearly set forth, which must be met. In order to enable the board to pass upon candidates fairly, certain qualifications are specified as "prima facie evidence of fitness" which (unless other facts derogatory to a candidate are also in evidence) will permit the board to pass the candidate. This so-called "prima facie evidence" is not required, but if the candidate can present such evi-

dence his application is the more readily passed upon. For instance, a candidate need not be a graduate of a college of engineering or architecture, but if he is, it is to his advantage. Likewise a candidate need not be a full member of one of the National technical societies or institutes, but if he has won such full membership it is greatly to his professional advantage.

In the preparation of this bill an experienced research engineer, Capt. Raymond J. Roark, was first employed to assist the chairman, and a preliminary draft prepared, based upon a comprehensive study of all the data and existing and proposed legislation available. This draft was then discussed and revised by the three Chicago members of the committee and the Chicago member of Council. It was then sent to each of the fifteen members of the committee for comments and amendments. After these communications had been received by the chairman and had all been collated, a meeting of the entire committee was called and held in Chicago, attended by eight members, Messrs. Arnold, Dunlap, Condron, Shenehon, Slater, Snyder, and Woermann, and Mr. Loweth, of Engineering Council.

Fourteen sessions were held in the five days, with a stenographic reporter present and all of the communications, as well as additional data gathered by the chairman, were carefully studied and a complete revision of the original draft was made, which draft met the unanimous approval of all the members in attendance. This later draft was carefully edited and sent to the entire committee for approval or amendment, subject to a final editing by the chairman and Mr. Shenehon.

The committee unanimously approved the bill as sent out, with minor suggestions for guidance in the final editing. This editing is now completed and the bill is submitted to Council with this report and with the recommendation that Council approve and endorse the same as a bill for an act of legislation in each and every State, for the regulation of the practice of engineering, architecture and land surveying. The bill, as tentatively proposed, is as follows:

Recommended Uniform Registration Law

Title.—An Act to regulate the practice of professional engineering, architecture and land surveying.

[Note: (*a*), In certain States further amplification of title may be required by law; (*b*) The brief terms "professional engineering", "architecture" and "land surveying" give simpler and clearer understanding of the activities affected by this act than any definition—Such definitions as have been devised have proven academic, difficult of proper inclusion and exclusion, confusing, laborious and frequently of great length; (*c*) Architectural work is basicly engineering, with an aesthetic element added. The architect is of nearer kin to the

structural engineer than is the electrical engineer. The model architectural definition of a building is that of an engineering structure. Architects form part of the membership of the American Society of Civil Engineers. Laws for the registration of architects and engineers must be either in parallel or in common. Assuming the best interests of each to lie in co-operation, and having in mind economical administration of a law, both are included in this act. Surveying is a function of engineering, but land surveying deals with land measurements involving property rights.]

The People of the State of .... enact:

Section 1.—In order to safeguard life, health and property, any person practicing or offering to practice professional engineering, architecture or land surveying in this State shall hereafter be required to submit evidence that he or she is qualified so to practice, and shall be registered as hereinafter provided, and from and after............ months after this Act becomes effective, it shall be unlawful for any person to practice or to offer to practice professional engineering, architecture or land surveying in this State, unless such person has been duly registered under the provisions of this Act.

[Note: (*d*), The constitutionality of this law is based on its promoting the public welfare by safeguarding life, health and property.]

Section 2.—Nothing in this Act shall be construed as requiring registration for the purpose of practicing professional engineering, architecture or land surveying by an individual, firm or corporation on property owned or leased by said individual, firm or corporation unless the same involves the public safety or health.

[Note: (*e*), Obviously no modern agriculturist should be prohibited from laying out and building the ditches or roads on his farm, or planning and building his own barn.]

Appointment of the Board

Section 3.—To carry out the provisions of this Act there is hereby created a State Board of Registration for professional engineers, architects and land surveyors, hereinafter called the "Board", consisting of seven members, who shall be appointed by the Governor within sixty days after this Act becomes effective. At least three members shall be professional engineers, and at least three members shall be architects. Not more than one member of said Board shall be from the same branch of the profession of engineering. The members of the first Board shall be appointed to serve for the following terms: Two members for one year; two members for two years; two members for three years,

and one member for four years; said terms ending on the first day of ....of the succeeding years. On the expiration of each of said terms the term of office of each newly appointed or reappointed member of the Board shall be for a period of four years and shall terminate on the first day of .... Each member shall hold over after the expiration of his term until the successor shall be duly appointed and qualified. The Governor may remove any member of the Board for misconduct, incompetency or neglect of duty. Vacancies in the membership of the Board, however created, shall be filled by appointment by the Governor for the unexpired term.

Qualifications and Expenses

Section 4.—Each member of the Board shall be a citizen of the United States and a resident of this State at the time of his appointment. He shall have been engaged in the practice of his profession for at least ten years and shall have been in responsible charge of work for at least five years. He shall be a member in good standing of a recognized society of professional engineers or architects, and except as provided in Section 5, shall be a registered professional engineer or a registered architect. Each member of the Board shall receive .... dollars ($........) per day for attending sessions of the Board or of its committees, and for the time spent in necessary travel, and, in addition, shall be reimbursed for all necessary traveling, incidental and clerical expenses incurred in carrying out the provisions of this Act.

[Note: (*f*). The per diem allowance of each member of the Board is not expected to be adequate compensation. High-grade professional men are expected to serve as a matter of good citizenship.]

Certificates, Privileges and Powers of the Board

Section 5.—Each member of the Board shall receive a certificate of appointment from the Governor, and before beginning his term of office he shall file with the Secretary of State the constitutional oath of office. Each member of the Board first created shall receive a certificate of registration under this Act from the Governor of this State. The Board or any committee thereof shall be entitled to the services of the Attorney General, in connection with the affairs of the Board, and the Board shall have power to compel the attendance of witnesses, may administer oaths and may take testimony and proofs concerning all matters within its jurisdiction. The Board shall adopt and have an official seal which shall be affixed to all certificates of registration granted; and shall make all by-laws and rules not inconsistent with law needed in performing its duty. Suitable office quarters shall be provided by the State for the use of the Board in the City of..........

Organization and Meetings of the Board

Section 6.—The Board shall hold a meeting within thirty days after its members are first appointed, and thereafter shall hold at least two regular meetings each year. Special meetings shall be held at such times as the by-laws of the Board may provide. Notice of all meetings shall be given in such manner as the by-laws may provide. The Board shall elect annually from its members a chairman, a vice-chairman and a secretary. A quorum of the Board shall consist of not less than two engineer and two architect members.

Receipts and Disbursements

Section 7.—The secretary of the Board shall receive and account for all moneys derived from the operation of this Act and shall pay them to the State Treasurer, who shall keep such moneys in a separate fund to be known as the "Fund of the Board of Registration for Professional Engineers, Architects and Land Surveyors", which fund shall be continued from year to year and shall be drawn against only for the purpose of this Act as herein provided. All expenses certified by the Board as properly and necessarily incurred in the discharge of its duties, including authorized compensations, shall be paid out of said fund on the warrant of the Auditor of the State issued on requisitions signed by the chairman and the secretary of the Board; provided, however, that at no time after this Act has been in effect for one year shall the total of warrants issued exceed the total amount of funds accumulated under this Act. The secretary of the Board shall give a surety bond satisfactory to the State Treasurer conditioned upon the faithful performance of his duties. The premium on said bond shall be regarded as a proper and necessary expense of the Board.

[Note: (*g*), The administration of the law is made ultimately self-supporting. The Legislature is not expected to appropriate money to accomplish the results contemplated.]

Records and Reports

Section 8.—The Board shall keep a record of its proceedings and a register of all applicants for registration showing for each, the date of application, name, age, educational and other qualifications, place of business and place of residence, whether or not an examination was required and whether the applicant was rejected, or a certificate of registration granted, and the date of such action. The books and register of the Board shall be prima facie evidence of all matters recorded therein. A roster showing the names and places of business and of residence of all registered professional engineers, architects and land surveyors shall be prepared by the secretary of the Board during the month of .... of each year; such roster shall be printed by the

State out of the fund of the Board as provided in Section 7, and a copy mailed to and placed on file by the clerk of each incorporated city, town and county in the State. On or before the ...... day of........ of each year the Board shall submit to the Governor a report of its transactions for the preceding year, and shall file with the Secretary of State a copy of such report together with a complete statement of the receipts and expenditures of the Board, attested by the affidavits of the chairman and the secretary, and a copy of the said roster of registered professional engineers, registered architects and registered land surveyors.

Applications for and Issuance of Certificates

Section 9.—The Board shall, on application therefor, on prescribed form and the payment of a fee of .... dollars ($........), issue a certificate of registration:

> [Note: (*h*), The application required should include a complete statement of an applicant's education and a detailed summary of his technical work. The statements made should be under oath, and should be supported by the recommendations of not less than two professional engineers, architects or land surveyors as vouchers.]

1.—To any person who submits evidence satisfactory to the Board that he or she is fully qualified to practice professional engineering, architecture or land surveying; or

2.—To any person who holds a like unexpired certificate of registration issued to him or her by proper authority in any State or territory of the United States, or in any province of Canada, in which the requirements for the registration of professional engineers, architects or land surveyors are of a standard satisfactory to the Board;

Provided, however, that no person shall be eligible for registration who is under twenty-five years of age, who is not a citizen of the United States or Canada, or who has not made declaration of his or her intention to become a citizen of the United States, who does not speak and write the English language, who is not of good character and repute, and who has not been actively engaged for six or more years in the practice of professional engineering, architecture or land surveying of character satisfactory to the Board. However, each year of teaching, or of study satisfactorily completed, of engineering or architecture in a school of engineering or architecture of standing satisfactory to the Board, shall be considered as equivalent to one year of such active practice.

> [Note: (*i*), The functions of the Board are largely administrative and judicial. The burden of presenting evidence of qualification is placed upon the applicant. The Board may in doubtful cases give technical examina-

tions; but the clear intent is to utilize other State agencies, as for instance the Engineering or Architectural schools, to submit as evidence the results of examinations, with recommendations as to competency.]

Unless disqualifying evidenee be before the Board, the following facts established in the application shall be regarded as prima facie "evidence, satisfactory to the Board", that the applicant is fully qualified to practice professional engineering, architecture or land surveying:

[Note: (*j*), When the law goes into effect a large percentage of practicing engineers, architects and land surveyors will be registered to preserve the status quo. Long-continued practice, graduation from a technical school of approved standing with subsequent years of practice, or membership in high-grade technical societies, in the absence of disqualifying facts, is accepted as prima facie evidence of qualification, as stated below.]

(*a*) Ten or more years of active engagement in professional engineering, architectural or land surveying work;

(*b*) Graduation, after a course of not less than four years, in engineering or architecture, from a school or college approved by the Board as of satisfactory standing, and an additional four years of active engagements in professional engineering, architecture or land surveying work;

(*c*) Full membership in the American Institute of Architects, American Society of Civil Engineers, American Institute of Chemical Engineers, American Institute of Electrical Engineers, American Society of Mechanical Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Naval Architects and Marine Engineers, or such other National or State engineering or architectural societies as may be approved by the Board, the requirements for full membership of which are not lower than the requirements for full membership in the professional societies or institutes named above.

Applicants for registration, in cases where the evidence originally presented in the application does not appear to the Board conclusive or warranting the issuance of a certificate, may present further evidence which may include the results of a required examination, for the consideration of the Board.

[Note: (*k*), The standard of qualification is set high for two reasons: The public welfare will be better promoted by maturer competency; and the prestige attaching to the term "Registered" will be more significant for the

professional men themselves. In requiring the younger, less experienced men to serve somewhat longer as assistants or understudies to older men, no hardship is imposed which will not be compensated by the fuller return in recognition when registration is achieved.]

In determining the qualifications of applicants for registration as architects, a majority vote of the architect members of the Board only, shall be required; and in determining the qualifications of applicants for registration as professional engineers or land surveyors, a majority vote of the engineer members of the Board only, shall be required.

[Note: (*l*), The acceptance for registration of engineers by the engineers on the Board, and of architects by the architects on the Board, places the judicial finding of fitness or unfitness in the hands of those best qualified to judge. In administrative matters and in the revocation of certificates, the Board acts as a unit.]

In case the Board denies the issuance of a certificate to an applicant, the registration fee deposited shall be returned by the Board to the applicant.

Certificates of registration shall expire on the last day of the month of .... following their issue or renewal and shall become invalid on that date unless renewed. It shall be the duty of the secretary of the Board to notify by mail every person registered hereunder of the date of the expiration of his certificate and the amount of the fee required for its renewal for one year; such notice shall be mailed at least one month in advance of the date of the expiration of said certificate. Renewal may be effected at any time during the month of .... by the payment of a fee of .... dollars to the secretary of the Board. The failure on the part of any registrant to renew his certificate annually in the month of..........as required above shall not deprive such person of the right of renewal thereafter, but the fee to be paid for the renewal of a certificate after the month of............shall be increased 10% for each month or a fraction of a month that payment for renewal is delayed; provided, however, that the maximum fee for a delayed renewal shall not exceed twice the normal fee.

[Note: (*m*), The amount of the fee to be paid by a registrant must be established by each State in the light of the number of fees to be expected, and the cost of administration.]

Revocation and Reissue of Certificates

Section 10.—The Board shall have the power to revoke the certificate of registration of any professional engineer, architect or land

surveyor registered hereunder who is found guilty of any fraud or deceit in obtaining a certificate of registration or of gross negligence, incompetency or misconduct in the practice of professional engineering, architecture or land surveying. Any person may prefer charges of such fraud, deceit, negligence, incompetency or misconduct against any professional engineer, architect or land surveyor registered hereunder; such charges shall be in writing and sworn to by the complainant and submitted to the Board. Such charges, unless dismissed without hearing by the Board as unfounded or trivial, shall be heard and determined by the Board within three months after the date on which they are preferred. A time and place for such hearing shall be fixed by the Board. A copy of the charges, together with a notice of the time and place of hearing shall be legally served on the accused at least thirty days before the date fixed for the hearing, and in the event that such service cannot be effected thirty days before such hearing, then the date of hearing and determination shall be postponed as may be necessary to permit the carrying out of this condition. At said hearing the accused shall have the right to appear personally and by counsel and to cross-examine witnesses against him or her and to produce evidence and witnesses in his or her defense. If after said hearing five or more members of the Board vote in favor of finding the accused guilty of any fraud or deceit in obtaining a certificate or of gross negligence, incompetency or misconduct in the practice of professional engineering, architecture or land surveying, the Board shall revoke the certificate of registration of the accused.

The Board may reissue a certificate of registration to any person whose certificate has been revoked, provided five or more members of the Board vote in favor of such reissue for reasons the Board may deem sufficient.

The Board shall immediately notify the Secretary of State and the clerk of each incorporated city, town and county in the State of its findings in the case of the revocation of a certificate of registration or of its reissuance of a revoked certificate of registration.

[Note: (*n*), Revocation is recognized as a serious procedure in its effect on professional reputation, and the right of hearing and contest is recognized and provided for.]

A new certificate of registration to replace any certificate lost, destroyed or mutilated, may be issued, subject to the rules and regulations of the Board. A charge of one dollar shall be made for such reissue.

Significance of Certificate—Seals

Section 11.—The issuance of a certificate of registration by this Board shall be evidence that the person named therein is entitled to

all the rights and privileges of a registered professional engineer, registered architect or registered land surveyor while the said certificate remains unrevoked or unexpired.

Each registrant hereunder shall upon registration obtain a seal of the design authorized by the Board, bearing the registrant's name and the legend "registered professional engineer", or "registered architect", or "registered land surveyor". Plans, specifications, plats and reports issued by a registrant may be stamped with said seal during the life of registrant's certificate, but it shall be unlawful for any one to stamp or seal any documents with said seal after the certificate of the registrant named thereon has expired or has been revoked unless said certificate has been renewed or reissued.

Unlawful Acts and Penalties

Section 12.—Any person who after this Act has been in effect ······ months is not legally authorized to practice professional engineering, architecture or land surveying in this State according to the provisions of this Act and shall so practice, or offer so to practice in this State, except as provided in Section 13 of this Act, and any person presenting or attempting to file as his own the certificate of registration of another, or who shall give false or forged evidence of any kind to the Board, or to any member thereof, in obtaining a certificate of registration, or who shall falsely impersonate any other practitioner, of like or different name, or who shall use or attempt to use an expired or revoked certificate of registration, shall be deemed guilty of a misdemeanor and shall for each such offense of which he is convicted be punished by a fine of not less than one hundred dollars ($100) nor more than five hundred dollars ($500), or by imprisonment for three months, or by both fine and imprisonment. However, nothing in this Act shall be construed as excluding any registered architect from the practice of professional engineering or as excluding any registered professional engineer from the practice of architecture.

[Note: (*o*), This Act not only gives prestige to the titles "Registered Professional Engineer", "Registered Architect" or "Registered Land Surveyors", but it prohibits the practice as principals of all persons not registered; (*p*) By reason of overlapping of the fields of engineering and architecture, a clear line of demarcation cannot be made between these two professions; (*q*) As this Act does not prohibit a chemical engineer from building a steel arch bridge, it appears inconsistent to prohibit an architect from building such a bridge, or a structural engineer from building a church. Ethical considerations and professional opinion must confine the scope of each person's practice to the fields in which he is a master.]

Exemptions

Section 13.—The following shall be exempted from the provisions of this Act:

1. Offering to practice in this State as a professional engineer, architect or land surveyor, by any person not a resident of and having no established place of business in this State.

[Note: (*r*), A professional card in a journal of National circulation is an "offer to practice" in any State in the Union. It would be manifestly unfair to compel a professional man to register in every State in which he may in this way, or by letter or otherwise, express his readiness to accept an engagement.]

2. Practice as a professional engineer, architect or land surveyor in this State by any person not a resident in this State and having no established place of business in this State, when this practice does not aggregate more than fifteen days in any calendar year; provided, that said person is legally qualified for such professional service in his own State or country.

[Note: (*s*), It is a distinct advantage to the people of any State to be able to call in for consultation a specialist from any other State. Such practice may be brief, and often of an emergency nature.]

3. Practice as a professional engineer, architect or land surveyor in this State by any person not a resident of and having no established place of business in this State, or any person resident in this State, but whose arrival in the State is recent; provided, however, such a person shall have filed an application for registration as a professional engineer, an architect or a land surveyor and shall have paid the fee provided for in Section 9 of this Act. Such exemption shall continue for only such reasonable time as the Board requires in which to consider and grant or deny the said application for registration.

4. Engaging in professional engineering, architecture or land surveying as an employee of a registered professional engineer, a registered architect or a registered land surveyor, or as an employee of a professional engineer, architect or land surveyor, authorized by Paragraphs 2 and 3 of this Section, provided that said practice may not include responsible charge of design or supervision.

5. Practice of professional engineering, architecture and land surveying solely as an officer or as an employee of the United States.

6. Practice of professional engineering, architecture or land surveying solely as an employee of this State or any political subdivision thereof, at the time this Act becomes effective and thereafter only until the expiration of the then existing term of office of such employee.

Corporations or Partnerships

Section 14.—A corporation or partnership may engage in the practice of professional engineering, architecture or land surveying in this State, provided the person or persons connected with such corporation or partnership in charge of the designing or supervision which constitutes such practice is or are registered as herein required of professional engineers, architects and land surveyors. The same exemptions shall apply to corporations and partnerships as apply to individuals under this Act.

Public Work

Section 15.—One year after this Act goes into effect, neither the State nor any county, township, city, town or village nor other political subdivision in the State, shall engage in the construction or maintenance of any public work involving professional engineering or architecture for which the plans, specifications and estimates have not been made by, and the construction and maintenance supervised by, a registered professional engineer, or a registered architect; provided, that nothing in this section shall be held to apply to such public work wherein the contemplated expenditure for the completed project does not exceed two thousand dollars ($2 000).

Land Surveying

Section 16.—Land surveying as covered by this Act refers only to surveys for the determination of areas or for the establishment or re-establishment of land boundaries and the subdivision and platting of land. Nothing in this Act shall be construed as prohibiting registered professional engineers or registered architects from making land surveys where such surveys are essential to engineering or architectural projects.

Repeal of Conflicting Legislation

Section 17.—All laws or parts of laws in conflict with the provisions of this Act are hereby repealed.

Engineering Council Approves Committee's Proposed Classification of Engineers.

A complete and definite classification for engineers in Federal, State, County, Municipal and Railroad service was approved by Engineering Council at its meeting on December 18th, 1919, when it adopted the classification proposed in the third progress report of its Committee on Classification and Compensation of Engineers, of which Arthur S. Tuttle, M. Am. Soc. C. E., is chairman. Eight grades are defined, five professional and three sub-professional, and the necessary qualifications are specified. A striking comparison of the results of

this latest investigation into Federal, State and Municipal service with those reported in 1917 by the committee of the American Society of Civil Engineers appointed to investigate the conditions of employment and compensation of civil engineers was pointed out in the committee report.

The extracts of this report which follow include, in addition to the classification and the above-mentioned comparison, an interesting tabulation of average salaries in Federal, State and Municipal service, with average ages of the incumbents and average salaries recommended by the engineers in charge. A schedule of salaries for engineers in city, State and National governmental employment is suggested by the Committee for discussion. The Committee asked for an appropriation of $10 000 for the purpose of continuing the investigation into present salaries and to insure publicity and progress in the effort to raise the level of engineering compensation. This is one of the items for which Engineering Council is making its appeal for funds, and the effective continuation of the work of the Committee is dependent upon the outcome of that appeal.

Findings and Conclusions of the Committee

The investigations have shown the lack of any adequate or consistent employment policy with respect to professional engineers. This is evidenced by the following conditions which are believed to be largely responsible for the unsatisfactory status of men engaged in this class of work:

1. Absence of any uniform system of grading of positions.
2. Lack of uniformity in titles of positions with respect to duties.
3. Inequalities in compensation for positions of the same grade.
4. Generally inadequate compensation for services rendered.

To the end that these conditions may be corrected and proper and equitable conditions of employment established, the following principles and practices are recommended by the Committee, though not yet acted upon by Council.

1. Positions should be classified in accordance with the type of work, and with the character of the duties to be performed and the qualifications necessary for their performance, as indicated by a system of grading.

2. Within the salary limits fixed for each grade, there should be a system of advancement through the grade based upon experience gained in the position and upon proof of increase in the proficiency of the employee in performing the duties of the grade.

3. Promotions from grade to grade should depend upon the existence of a vacancy in the higher grade and proof that the employee is qualified to fill the vacancy.

4. The determination of salary adequate to procure for and retain in engineering work a high class of employees, should take into account and properly weigh the following considerations:

(*a*) The capital invested, both in money and in time, in obtaining the requisite fundamental training.
(*b*) The amount and character of experience and the degree of personal ability required.
(*c*) The relative value of the classes of work to be performed.
(*d*) The amount paid for similar service in other lines of work.
(*e*) The amount necessary to enable the employee to maintain a standard of living commensurate with the general standards of the community for positions of similar dignity and responsibility.

5. In the interest of an adequate social policy, no position likely to be occupied by individuals of an age to assume family responsibilities should fail to pay an amount sufficient to permit the maintenance of the average family in reasonable decency and comfort.

6. In the interest of the employees as a whole and of the employer, a system should be established by which employees who fail to maintain satisfactory standards of service should be removed, transferred, demoted, or retired as may be equitable in the circumstances.

Classification of Engineering Positions in Federal, State, County, Municipal and Railroad Services

The grades proposed, which appear to be well adapted to use not only in all of the services represented but also for all other forms of engineering activities, have been divided into two classes, the Professional Service being deemed to include men who have received an engineering degree from an educational institution of recognized standing or who have obtained similar qualifications through practice of the profession and by mastering the fundamentals of engineering science, while the Sub-Professional Service includes assistants with at least a high school education, who enter upon the practice of the profession in the performance of responsible duties for which an engineering training is not essential, but who through experience and study may fit themselves for the higher grades. The classification is as follows:

PROFESSIONAL SERVICE

Grade 1.—Chief Engineer

Duties.—To act in chief administrative charge of a technical organization, or of a main division thereof; to determine the general policies of the organization under the limitations imposed by law, regulation, or other fixed requirement; to have final responsibility for the preparation of reports, cost estimates, designs, and specifications and for the

construction, maintenance, or operation of engineering works or projects; to have full charge of the collection and presentation of data for and the conduct of valuation proceedings; to conduct or direct the most comprehensive lines of engineering research.

Qualifications.—Training and experience of a character to give substantial evidence of engineering knowledge and ability or of executive capacity of highest order along lines of work similar to those involved in the position to be occupied and of at least twelve years' duration, of which at least four years shall have been spent in duties of Engineer, or their equivalent, and at least five years in responsible charge of important work or projects. Fundamental training equivalent to that represented by professional degree granted upon the completion of a standard course of engineering instruction in an educational institution of recognized standing or, in absence of such degree, at least four years of additional experience. The completion of each full year of such standard course shall be considered the equivalent of one year of such additional experience.

Grade 2.—Engineer

Duties.—Under general administrative direction and within the limits of the general policies of the organization, to have responsible charge of and to initiate and determine policies for a major subdivision of an organization; to prepare for final executive action reports, cost estimates, designs, specifications, and valuation studies and data; to have immediate charge of the construction, maintenance, or operation of engineering works or projects of major importance; to conduct or direct major lines of engineering research; or to furnish for executive action expert or critical advice on engineering works, projects or policies.

Qualifications.—Active professional practice or executive charge of work for at least eight years, of a character to demonstrate a high degree of initiative and of ability in the administration, design, or construction of engineering work or projects of major importance, of which at least three years shall have been spent in duties of Senior Assistant Engineer, or their equivalent, and at least three years in responsible charge of work. Fundamental training equivalent to that represented by professional degree granted upon the completion of a standard course of engineering instruction in an educational institution of recognized standing or, in absence of such degree, at least four years of additional experience. The completion of each full year of such standard course shall be considered the equivalent of one year of such additional experience.

Grade 3.—Senior Assistant Engineer

Duties.—Under general administrative and technical direction, to be in responsible charge of an intermediate division of an organization;

to exercise independent engineering judgment and assume responsibility in studies and computations necessary for the preparation of reports, cost estimates, designs, specifications, or valuations; to have immediate charge of the construction, maintenance, or operation of important engineering works or projects; or to conduct or direct important lines of engineering research.

Qualifications.—Active professional practice or executive charge of work for at least five years, of which at least three years shall have been spent in duties of Assistant Engineer, or their equivalent, with at least one year in responsible charge of work. Fundamental training equivalent to that represented by professional degree granted upon the completion of a standard course of engineering instruction in an educational institution of recognized standing or, in absence of such degree, at least four years of additional experience. The completion of each full year of such standard course shall be considered the equivalent of one year of such additional experience.

Grade 4.—Assistant Engineer

Duties.—Under specific administrative and technical direction, to be responsible for the conduct of the work of a minor subdivision of an organization; to collect and compile data for specific items of engineering studies; to take immediate charge of field survey projects and of the design and construction of minor engineering work; to lay out and develop work from specifications and to supervise the work of a drafting or computing force; or to conduct specific tests or investigations of apparatus, material, or processes.

Qualifications.—Experience for at least two years in duties of Junior Assistant Engineer or their equivalent. Fundamental training equivalent to that represented by professional degree granted upon the completion of a standard course of engineering instruction in an educational institution of recognized standing or, in absence of such degree, at least four years of additional experience. The completion of each full year of such standard course shall be considered the equivalent of one year of such additional experience.

Grade 5.—Junior Assistant Engineer

Duties.—Under immediate supervision, to perform work involving the use of surveying, measuring, and drafting instruments; to take charge of parties on survey or construction work; to design details from sketches or specifications; to compute and compile data for reports or records; to inspect or investigate minor details of engineering work; or to perform routine tests of apparatus, material, or processes.

Qualifications.—No experience required other than that involved in securing a professional degree upon the completion of a standard course

of engineering instruction in an educational institution of recognized standing; but in absence of such degree, a high school education or its equivalent is required and at least four years' experience in the use of surveying, measuring or drafting instruments, or the computation and compilation of engineering data, together with evidence of a knowledge of the fundamentals of engineering science sufficient, with further experience, to qualify for the higher professional grades. The completion of each full year of such standard course of engineering instruction shall be considered as the equivalent of one year of experience.

SUB-PROFESSIONAL SERVICE

Grade 6.—Senior Aid, Office

Duties.—To supervise the plotting of notes and maps, and to direct the work of a drafting or computing squad.

Qualifications.—Experience for at least five years in tracing, lettering, drafting, and computing, of which at least three years shall have been spent in the duties of draftsman. Education equivalent to graduation from high school. The completion of each full year of a standard course of engineering instruction in an educational institution of recognized standing shall be considered as the equivalent of the experience otherwise required, with the provision, however, that at least one year shall have been spent in the duties of draftsman.

Grade 6.—Senior Aid, Field

Duties.—To direct work of field party on surveys or construction; to keep survey notes and engineering records; to supervise construction or repair work; to direct the work of computing surveys and estimates; to direct the work of making minor engineering computations.

Qualifications.—Experience for at least five years in the use and care of surveying instruments, of which at least three years shall have been spent in the duties of instrumentman. Education equivalent to graduation from high school. The completion of each full year of a standard course of engineering instruction in an educational institution of recognized standing shall be considered as the equivalent of the experience otherwise required, with the provision, however, that at least one year shall have been spent in the duties of instrumentman.

Grade 7.—Aid, Office

Duties.—To prepare general working drawings where design is furnished; to plot notes and prepare maps; to design simple structures; to make computations and compile data for reports and records; to check plans, surveys, and other engineering data.

Qualifications.—Experience for at least two years in tracing, lettering, drafting, and computing. Education equivalent to graduation from high school and familiarity with the use of the slide rule, and of logarithmic and other simple mathematical tables. The completion of each full year of a standard course of engineering instruction in an educational institution of recognized standing shall be considered as the equivalent of the experience otherwise required.

Grade 7.—Aid, Field

Duties.—To run surveying instruments and to adjust and care for same; to compute surveys and estimates; to make minor engineering computations; to inspect incidentally construction or repair work.

Qualifications.—Experience for at least two years in the duties of rodman. Education equivalent to graduation from high school and familiarity with the construction, operation, and care of surveying instruments. The completion of each full year of a standard course of engineering instruction in an educational institution of recognized standing shall be considered as the equivalent of the experience otherwise required.

Grade 8.—Junior Aid, Office

Duties.—To trace and letter maps and plans; to make simple drawings from sketches and data; to make minor calculations.

Qualifications.—Education equivalent to graduation from high school.

Grade 8.—Junior Aid, Field

Duties.—To run tape or leveling rod; to perform other miscellaneous subordinate duties in survey party in field or office, as directed.

Qualifications.—Education equivalent to graduation from high school.

Experience Equivalents for Post-Graduate Work

The completion of each full year of post-graduate work in the specific subject of study or investigation appropriate to a particular service or branch of service shall be considered the equivalent of one and one-half years of general experience, but such substitution shall not thus be made for more than four years of such experience or be considered as reducing the requirements in any grade of the number of years engaged in the conduct or direction of responsible work.

An examination of the schedule shows that the minimum experience requirements for the various grades may be briefly summarized as follows:

Service	Grade	Experience in Years With Degree in Engineering	Experience in Years Without Degree in Engineering
Sub-professional ...	8—Junior Aid........	0	0
	7—Aid	0	2
	6—Senior Aid........	0	5
Professional	5—Junior Assistant Engineer	0	4
	4—Assistant Engineer	2	6
	3—Senior Assistant Engineer	5	9
	2—Engineer	8	12
	1—Chief Engineer ...	12	16

Some Title Equivalents in Common Use

The following table illustrates the practicability of adapting the proposed classification to any particular grade or branch of the engineering service and in such a way as to clearly retain a description of the relative rank.

PROFESSIONAL SERVICE

1—Chief Engineer

Chief Engineer
State Engineer
City Engineer
Chief Engineer of Maintenance of Way
Deputy Chief Engineer
Deputy State Engineer
Deputy City Engineer
Director, etc.

2—Engineer

Electrical Engineer
Mechanical Engineer
Mining Engineer
Chemical Engineer
Bridge Engineer
Sanitary Engineer
Tunnel Engineer
Maintenance of Way Engineer
Signal Engineer
Highway Engineer
Division Engineer
District Engineer
Sewer Engineer
Topographical Engineer
Landscape Engineer
Hydraulic Engineer
Geodetic Engineer
Structural Engineer
Valuation Engineer
Designing Engineer, etc.

3—Senior Assistant Engineer

Senior Assistant Electrical Engineer
Senior Assistant Mechanical Engineer
Senior Assistant Mining Engineer
Senior Assistant Chemical Engineer
Senior Assistant Bridge Engineer, etc.

4—Assistant Engineer

Similar to Senior Assistant Engineer

5—Junior Assistant Engineer

Engineer Inspector, etc.

SUB-PROFESSIONAL SERVICE

6—Senior Aid

Office: Chief Draftsman
Chief Computer

Field: Chief Instrumentman
Chief Inspector

7—Aid

Office: Draftsman
Computer

Field: Instrumentman
Inspector

8—Junior Aid

Office: Junior Draftsman
Tracer

Field: Rodman
Tapeman

Striking Comparison of Results of Investigations Into Compensation

In 1913 a committee was appointed by the Board of Direction of the American Society of Civil Engineers to investigate the conditions of employment and compensation of civil engineers. This committee was headed by the late Alfred Noble, Past-President, Am. Soc. C. E., who was succeeded as chairman by Nelson P. Lewis, M. Am. Soc. C. E. In its final report, presented at the Annual Meeting of the Society held in 1917, the committee gave the results of its canvasses, comprising returns from 6 378 engineers, of whom 1 319 were non-members. The distribution among the various services of such returns as could be classified showed an average compensation as follows:

Service	Number of Classified Men	Average Compensation
States and Counties	387	$2 735
National Governments	575	2 899
Municipalities	764	2 994
Technical Schools	262	3 240
Railroads	814	3 325
Private Companies	2 198	4 240
Consulting Engineers	620	6 737
Contractors	165	7 678
	5 785	$4 032

The committee advised that the analysis of the returns showed that the pay received by members of the Society was generally about 25% above that of non-members. It also stated that an effort had been made to obtain information from Railroad, Municipal, State, and Federal Departments but that the officials in authority considered it impracticable to undertake a collection of the desired data, and in the absence of this co-operation no headway could be made. The committee also reported that from the meager information obtained it was "convinced that the compensation for engineering work compares favorably with that received by men of any other profession", and that there was need for "better trained engineers rather than of more engineers".

That a radical change of heart has since taken place on the part of responsible department heads is clearly evidenced by the fact that practically the entire Federal engineering service, except the War Department, has co-operated in the present inquiry, as have also 42% of the state officials, and 70% of the municipal officials, and that the financial status of 10 089 men in these grades has now been revealed as compared with a total of 1 726 men, in the same classes of service, who replied to the 1913-1916 inquiry. It also appears that the respondents in the case of the previous investigation were largely confined to the classes receiving maximum compensation, the average rate of present compensation shown by the new return being as follows:

Service	Number of Men	Average Compensation
Federal Government—Navy Department.......	594	$2 474
Federal Government—(excluding War and Navy Departments)	3 956	1 814
Federal Government (excluding War Department)	4 550	1 900
State	2 222	1 700
Municipal	3 317	1 820

In comparing these returns with those received by the previous committee, the decrease in the value of the dollar should also be borne in mind.

Results from Questionnaires

Tables 1, 2 and 3 include partial results of the analysis of Federal, State and Municipal returns from questionnaires received up to the date of the committee report, December 15th, 1919.

It is thus disclosed that the average compensation for grades representing 68% of the engineers in the Federal Service, other than the War Department, and 86% of those in State and Municipal Service, is less than is required for the support of a family

TABLE 1.—FEDERAL SERVICE, SUMMARY OF PRESENT SALARIES BY GRADES.

Grade.	General description of duties.	16 Engineering Bureaus in Civil Establishments.					4 Engineering Bureaus in Navy Department.				
		No. of persons.	Present pay per annum.			Per cent. increase of the average since July 1, 1915.	No. of persons.	Present pay per annum.			Per cent. increase of the average since July 1, 1915.
			Average.	Maximum.	Minimum.			Average.	Maximum.	Minimum.	
1	Chief administrative officer having full charge of organization including determination of policy.....	15	$5 867	$10 000	$4 500	3.0	2	$9 450	$9 900*	$9 000*	0.0
2	Chief of major subdivision in responsible charge of large unit..	83	3 801	7 500	1 800	5.0	4	6 381	9 000*	5 200	0.0
3	Chief of intermediate subdivision in responsible charge..	209	3 104	5 000	1 800	9.9	22	4 312	5 634	2 304	57.6
4	Chief of minor subdivision..........................	846	2 222	4 500	1 020	9.0	54	3 600	4 883	2 304	58.2
5	On general duty under direction but requiring special education and training and the use of initiative and originality....................................	1 353	1 719	3 000	1 000	13.3	192	2 818	3 756	1 878	52.2
6 and 7	On subordinate duty requiring special education or training but not requiring special originality.......	1 092	1 293	2 817	600	12.0	218	1 954	4 257	1 500	38.4
8	On subordinate duty but not requiring special education, training, or originality......................	169	975	1 340	480	19.3	81	1 379	2 254	1 002	37.2
..	On special duty of responsible character requiring special qualifications and initiative.................	189	1 812	7 500	1 200	3.9	21	2 717	4 382	1 628	1.3
	Total..	3 956					594				

* Naval Officers, all others are civilian.

TABLE 2.—STATE SERVICE, ANALYSIS OF RETURNS SHOWN BY 35 QUESTIONNAIRES FROM 27 STATES.

Position.	Number of persons now in position.	Age, Years.*		Average Compensation per Annum.*			Per Cent. Increase in Compensation over July 1st, 1915.*	
		Range.	Average.	July 1st, 1915.	July 1st, 1919.	Recommended.†	Actual on July 1st, 1919	Recommended.†
PROFESSIONAL.								
Chief Engineer	31	30-70	41	3 743	4 481	7 124	20	90
Deputy Chief Engineer	19	30-51	38	3 352	3 616	4 477	8	34
Engineer	80	30-50	37	2 530	3 019	3 934	19	56
Senior Assistant Engineer	111	30-50	32	1 981	2 429	3 222	23	63
Assistant Engineer	396	27-42	33	1 657	2 140	2 758	29	66
Junior Assistant Engineer	529	21-36	27	1 130	1 595	2 100	41	86
Staff	1 166	21-70		1 590	2 070	2 730	30	72
SUB-PROFESSIONAL.								
Senior Draftsman	29	25-40	31	1 508	1 868	2 327	24	54
Draftsman	141	22-50	28	1 224	1 653	1 944	35	59
Junior Draftsman	110	20-25	22	924	1 227	1 394	33	51
Chief Instrumentman	61	24-40	27	1 297	1 611	1 915	24	48
Instrumentman	193	22-30	23	1 243	1 498	1 773	21	43
Rodman	522	18-26	20	791	1 057	1 148	34	45
Staff	1 056	18-50		995	1 290	1 470	30	48
Entire service	2 222	18-70		1 310	1 700	2 130	30	63

* Based on such returns as are complete.

† As recommended by the engineering heads replying to questionnaire.

TABLE 3.—MUNICIPAL SERVICE, ANALYSIS OF RETURNS SHOWN BY 66 QUESTIONNAIRES FROM 40 CITIES.

Position.	Number of persons now in position.	Age—Years.*		Average Compensation per Annum.*			Per cent. increase in Compensation over July 1st, 1915.*	
		Range.	Average.	July 1st, 1915	July 1st, 1919	Recommended.†	Actual on July 1st, 1919	Recommended.†
Professional.								
Consulting Engineer	8	39-70	55	5 457	6 410	8 550	18	57
Chief Engineer	64	30-64	44	5 424	5 467	7 465	1	38
Deputy Chief Engineer	19	35-60	48	4 624	4 901	6 320	6	37
Engineer	165	30-68	46	3 446	3 679	4 749	7	38
Senior Assistant Engineer	265	30-64	41	2 428	2 616	3 293	8	36
Assistant Engineer	505	27-53	40	1 902	1 999	2 613	5	37
Junior Assistant Engineer	452	25-45	34	1 415	1 548	1 812	9	28
Staff	1 478	25-70		2 230	2 370	3 020	6.5	36
Sub-Professional.								
Senior Draftsman	100	28-53	42	1 777	1 982	2 356	12	33
Draftsman	442	25-65	35	1 395	1 626	2 008	17	44
Junior Draftsman	118	21-48	26	1 055	1 205	1 439	14	36
Chief Instrumentman	88	28-53	40	1 454	1 700	2 162	17	49
Instrumentman	448	22-52	38	1 174	1 426	1 737	21	48
Rodman	643	17-52	32	868	1 056	1 352	22	56
Staff	1 839	17-65		1 160	1 370	1 700	18.5	47
Entire Service	3 317	17-70		1 640	1 820	2 290	11	40

* Based on such returns as are complete.

† As recommended by the engineering heads replying to questionnaire.

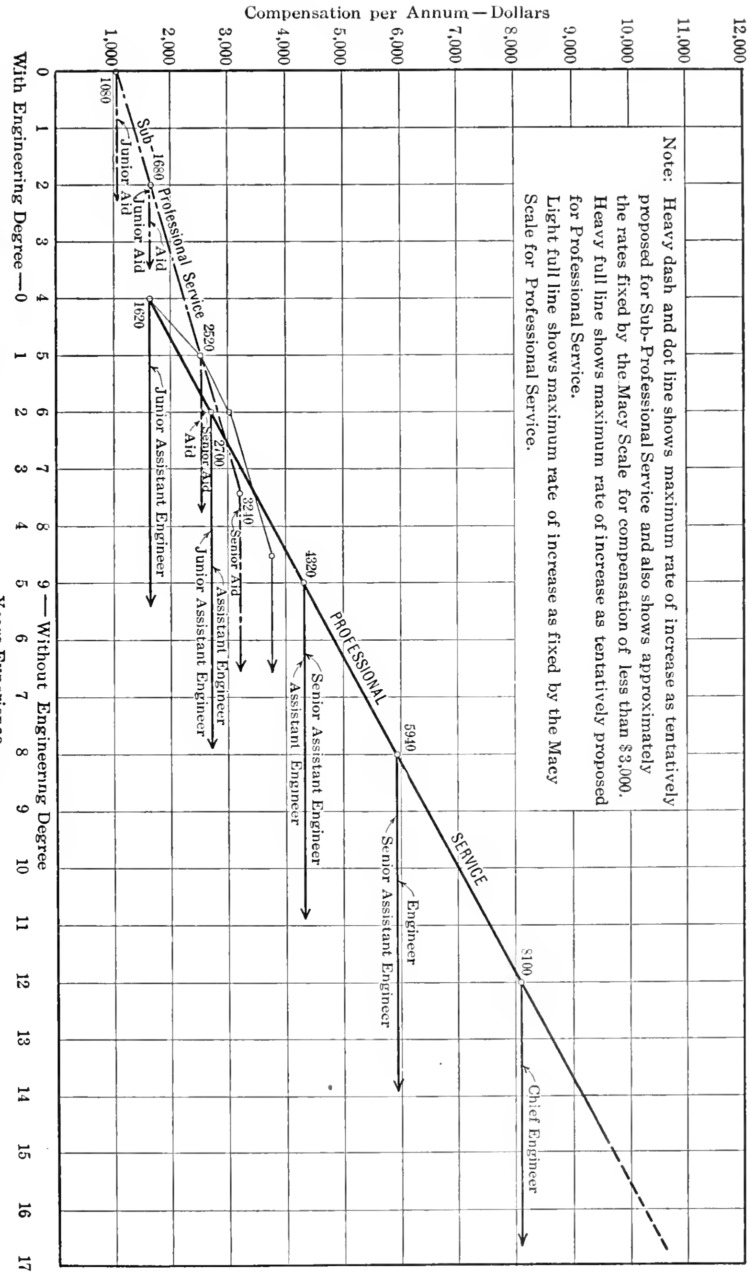

DIAGRAM SHOWING MAXIMUM RATE OF PROGRESS THROUGH THE VARIOUS GRADES AND COMPENSATION TENTATIVELY PROPOSED

on a scale sufficient to provide for necessities (assumed at $2 200 per annum), to say nothing of the expense of giving children anything like the education with which the breadwinner was equipped.

It would seem reasonable to assume that men in the "Junior Aid" grade have not reached an age which would require compensation sufficient to support a family, but that the salary limitation for men in higher grades should clearly be sufficient to meet this need. On this basis it is safe to state that with anything like suitable compensation, not more than approximately 25% of the entire service, if properly organized, should receive less than $2 200 per annum. The investigation made by the State and Municipal Section shows that the average age of the present incumbents of the lowest grades is actually about 27 years; if they are to be adequately provided for as permanent employees, the percentage of men to receive less than $2 200 is clearly negligible.

A comparison with the pay of the industrial worker who serves under the engineer also bears testimony to the fact that, while admitted by none as to value, the actual compensation for brawn is to-day greater than for engineering brain. The need for setting up some scale of compensation for the engineer to correct this serious condition is, therefore, obvious, as is also that for the inquiry now being carried on by the Committee. Unless a radical improvement can be brought about, it seems evident that the profession cannot attract to or retain in it men of the caliber required to command the respect in which it has heretofore been held by the public, and that so long as they are continuously struggling with the problem of making even a bare living, their efficiency will be minimized and their incentive to work with other than a purely selfish interest will be lacking.

That a serious condition of unrest exists in the Municipal and State services is clearly evidenced by explicit statements in this respect in 44% of the questionnaires returned, while in only 13 of these services were conditions as to morale reported to be satisfactory.

From the investigation made by each of the sections of the Committee, it appears that the heads of sixteen engineering bureaus in the Federal Government (excluding the Navy Department) have recommended an average increase in present compensation averaging about 59%, while similar increases in the State and Municipal Services, as recommended by the engineering heads, average 26 per cent.

As a result of the inquiry now in progress under the direction of the Congressional Joint Commission on Reclassification of Salaries, the attention of all members of the Federal Service has been drawn to this question in such a way as to make it one of close study and analysis, which condition doubtless accounts for the comparatively modest recommendation made by the representatives of the State and Municipal Services, whose reply to our inquiry has been individual and who have

doubtless been confronted with the necessity of recognizing relationship to other workers in the same services in whose interests no concerted move of this character has been attempted.

Your Committee is impressed with the method which has been followed by the Federal Section in setting up a standard of compensation based on a readjustment to the new conditions as to cost of living, this being dependent on an award made on October 24th, 1918, by the Shipping Wage Adjustment Board, which was designed to provide a uniform national wage scale for all shipbuilding workers, including a scale of compensation for draftsmen and copyists. It is also understood that this wage scale, which is generally known as the Macy Scale, has since been adapted with modifications to the needs of certain bureaus in the Navy Department. In the accompanying diagram there is illustrated a comparison of the compensation fixed under the Macy Scale with the maximum rates suggested by the Federal Section. A further comparison has also been made with scales proposed by other organizations, which seems to justify the schedule of salaries now suggested by the Committee for discussion, which is as follows:

Schedule of Salaries Suggested for Discussion

Grade	Total Years Experience Required to Qualify: With Professional Degree	Total Years Experience Required to Qualify: Without Professional Degree	Salary Range: Minimum	Salary Range: Maximum
8—Junior Aid	....	0	$1 080	$1 560
7—Aid	....	2	1 680	2 400
6—Senior Aid	....	5	2 520	3 240
5—Junior Assistant Engineer	0	4	1 620	2 580
4—Assistant Engineer	2	6	2 700	4 140
3—Senior Assistant Engineer	5	9	4 320	5 760
2—Engineer	8	12	5 940	No limit
1—Chief Engineer	12	16	8 100	No limit

Applying the average proposed salary to the present incumbents of these positions as reported in the State and Municipal services, it will be found that there would be a resulting increase in annual compensation totaling about $5 500 000 as compared with a total increase of $2 500 000 recommended by the service heads, against which should, however, be charged the economy growing out of the increased efficiency brought about by a restoration of morale.

The Committee is not prepared at this time to recommend the adoption of any definite schedule of compensation, and it is not at all clear as to the wisdom of fixing even a minimum limit on the highest grades of service or of keeping the maximum of one grade below the minimum of the grade above, all of which questions are now receiving its serious consideration, as is also the question concerning the provision to be

made for advancing within the limits of a grade, for which a plan is suggested by the Federal Section. Under this plan it is proposed at yearly intervals, through ratings determined by a Personnel Board, to provide for awarding an increase in compensation to three-fourths of the men in a grade receiving less than the maximum compensation of the grade, who through fitness and industry have shown themselves to be of increased value to the service. Those in the highest third of this preferred list would each receive the maximum rate of increase, which under the proposed scale would be $480, while each of the next two-thirds would receive an increase of $240, the latter figure corresponding with what would then be the average increase for all of the men in the grade.

It would seem to the Committee that, pending the completion of the investigation, the scale of compensation herein presented and the plan for promotion within a grade is adapted to general use in all branches of engineering service. The Committee believes, however, that a general discussion of this question is desirable.

The chairmen of the sections of the Committee are as follows: State and Municipal Section, Arthur S. Tuttle, New York City; Railroad Section, Francis Lee Stuart, New York City; Federal Government Section, John C. Hoyt, Washington, D. C.—all members of the Society. The other members of the Committee are: Charles Whiting Baker, New York City; M. O. Leighton, M. Am. Soc. C. E., Washington, D. C.; Frank H. Clark, New York City; Bion J. Arnold, M. Am. Soc. C. E., Chicago; M. M. O'Shaughnessy, M. Am. Soc. C. E., San Francisco; F. W. Cappelen, M. Am. Soc. C. E., Minneapolis; J. S. Conway, M. Am. Soc. C. E., Washington, D. C., and O. C. Merrill, M. Am. Soc. C. E., Washington, D. C.

Approval Given to Principles Adopted by State Reconstruction Commission

At its meeting on December 18th, 1919, Engineering Council, on recommendation of its Advisory Committee to the Reconstruction Commission of the State of New York, approved the principles of the Report of that Commission reducing 187 offices, boards, and commissions in the State to 20 departments, decreasing the number of elected executive officers to three, Governor, Lieutenant-Governor, and Controller, and proposing a businesslike budget system. The Secretary was directed to forward a notice of the approval to the Reconstruction Commission.

National Department of Public Works Convention

Alfred D. Flinn, M. Am. Soc. C. E., and Secretary of Engineering Council, has been appointed as delegate to represent the Society at the Convention of the National Department of Public Works Association (formerly the Engineers', Architects' and Constructors' Conference

on National Public Works) on January 13th-14th, 1920, at Washington, D. C. This convention was called to intensify the interest in the movement to establish a National Department of Public Works initiated at the Conference in Chicago in April, 1919, to broaden the scope of the organization, to discuss procedure and to adapt future activities to the developments that have taken place since the former Conference. Provision has been made for a general experience meeting on campaign methods and problems and the following special addresses are scheduled: "Practical Results to Be Achieved by a National Department of Public Works", by Representative Frank C. Reavis; "Economies Secured by Standardization of Construction", by Gen. R. C. Marshall, Jr., M. Am. Soc. C. E., Chief of the Construction Division, U. S. Army; "What a Department of Public Works Has Done for Illinois", by Governor Frank O. Lowden.

President Issues Order Constituting Board of Surveys and Maps

As a result of the conference of representatives of the Federal map-making organizations held at Washington, D. C., in September, 1919, following a letter addressed to the President by Engineering Council on July 1st, 1919, requesting such a conference, the President, through the Secretary of War, has issued the following executive order establishing a Federal Board of Surveys and Maps:

"In order to co-ordinate the activities of the various map-making agencies of the executive departments of the Government, to standardize results, and to avoid unnecessary duplication of work, I hereby constitute a Board of Surveys and Maps, to be composed of one representative of each of the following organizations:

1. Corps of Engineers, U. S. Army.
2. U. S. Coast and Geodetic Survey, Department of Commerce.
3. U. S. Geological Survey, Department of Interior.
4. General Land Office, Department of Interior.
5. Topography Branch, Post Office Department.
6. Bureau of Soils, Department of Agriculture.
7. U. S. Reclamation Service, Department of Interior.
8. Bureau of Public Roads, Department of Agriculture.
9. Bureau of Indian Affairs, Department of Interior.
10. Mississippi River Commission, War Department.
11. U. S. Lake Survey, War Department.
12. International (Canadian) Boundary Commission, Department of State.
13. Forest Service, Department of Agriculture.
14. U. S. Hydrographic Office, Navy Department.

"The individual members of this Board shall be appointed by the Chiefs of the various organizations named and shall serve without additional compensation.

"The Board is directed to make recommendations to the several Departments or to the President for the purpose of co-ordinating all map-making and surveying activities of the Government and to settle

all questions at issue between Executive Departments relating to Surveys and Maps in so far as their decisions do not conflict with existing laws.

"This Board shall perfect a permanent organization and shall hold meetings at stated intervals, to which representatives of the map-using public shall be invited for the purpose of conference and advice.

"This Board shall establish a central information office in the U. S. Geological Survey for the purpose of collecting, classifying and furnishing to the public information concerning all map and survey data available in the several Government Departments and from other sources.

"All Government Departments will make full use of the above board as an advisory body and will furnish all available information and data called for by the Board.

"So much of the Executive Order of August 10, 1906, as grants additional advisory powers to the United States Geographic Board is hereby rescinded and these additional powers are transferred to the Board of Surveys and Maps."

Co-operation with American Institute of Architects

As a result of the following telegram signed by Mr. E. J. Russell, of St. Louis, Mo., dated December 17th, 1919:

"On behalf of the American Institute of Architects you are requested to appoint a Committee of three to co-operate with a similar Committee from the Institute for the purpose of co-operating on matters of mutual interest and benefit. Our Committee has been appointed and is ready to work at your convenience."

it was voted at the December meeting of Engineering Council:

"That this invitation be cordially accepted and that a committee of three be appointed by the Chair to co-operate with the American Institute of Architects."

Proposed Budget for 1920.

On recommendation of the Executive and Finance Committees, in joint meeting, December 1st, 1919, the following budget to carry out the work planned by Engineering Council for the year 1920 was adopted:

EXPECTED INCOME

Founder Societies	$12 000	
Other member societies	3 000	
Other sources	30 000	$45 000

PROPOSED EXPENDITURES

New York office	$12 000	
Washington office	12 000	
Committee on Classification and Compensation of Engineers	10 000	
Committees	5 000	
Contingencies	6 000	$45 000

It was voted "That Council's budget for the coming year be not less than $45 000 and that every possible effort be made to raise funds of that amount"; and, "that the Secretary be instructed to control expenditures from time to time in accordance with the tangible income."

Result of Appeal for Funds

As a temporary expedient, Engineering Council recently mailed to 50 000 engineers an appeal for funds to carry on its work, an extraordinary measure necessitated by present financial conditions resulting from the war. Engineers are expecting much of Council and commending the work which it has done. In order, however, that Council may continue its work for professional welfare and civic service, not less than $45 000 are needed for 1920. Of this amount, $30 000, at least, must come from general contributions. Up to January 7th, 1920, a total of 701 contributions have been received, amounting to $4 914. They range from $1 to $100 each, and average $7, and have come from all parts of the country with practically uniform distribution of the contributors over the various sections.

Military Affairs Committee

Engineering Council, after careful study, has appointed a Committee on Military Affairs to consider the relationships which can and should exist between the engineering and scientific technical men of the country and the country's military establishment, together with the best organization of the military establishment to utilize the country's resources in technically trained men, both within and without the military and naval services. The members of the Committee are:

Civilians Who have not been in Uniformed Service:

Harold W. Buck, Past-President, A. I. E. E.
Paul G. Brown, M. Am. Soc. C. E.
George Gibbs, Past-President, Am. Inst. of Cons. Engrs., M. Am. Soc. C. E., A. S. M. E., A. I. E. E.
T. Spencer Miller, M. Am. Soc. C. E., A. I. M. E., A. S. M. E.
Leonard Waldo, A. I. M. E., A. S. M. E., A. I. E. E.

Men Who have been in Uniformed Service:

Roger D. Black, M. Am. Soc. C. E.
Fred J. Miller, President, A. S. M. E.
William Barclay Parsons, M. Am. Soc. C. E.
F. A. Snyder, M. Am. Soc. C. E.
George D. Snyder, M. Am. Soc. C. E.

The Executive Committee of Engineering Council selected Col. William Barclay Parsons as Chairman of the Military Affairs Committee, and the Committee elected Col. George D. Snyder, Secretary The Secretary's address is care of Jacobs and Davies, 30 Church St., New York City.

Committees to Consider Types of Government Contracts and Payment for Estimating

For consideration of types for Government contracts, Engineering Council has appointed the following Committee: Arthur P. Davis, Chairman, D. K. Boyd, Harold W. Buck, J. A. Capp, Peter Junkersfeld, W. M. McFarland, Admiral H. H. Rousseau, and Col. Clarence O. Sherrill. Some Government departments have given assurance of their interest and co-operation in the work of this Committee.

On the subject of "Payment for Estimating", Engineering Council has appointed three conferees: T. L. Condron, Ralph Modjeski, and S. G. Neiler, who are collaborating with an equal number of representatives each of the American Institute of Architects and the Associated General Contractors of America.

Visit of Representative of National Association of Italian Engineers

Capt. Paul Tuccimei, a member of the Executive Board of the Associazione Nazionale degli Ingegneri Italiani and a member of the Italian Mission to the International Trade Conference in the United States, visiting the office of Engineering Council, discussed the sociological and industrial problems in Italy, and those of engineering organization. His statements might have been those of an American about conditions in the United States. The same subordination of technical men in Italy to politicians, military men and lawyers has resulted in the same economic and governmental and military inefficiency, and in unnecessarily large loss of life and money, in peace and in war. The same multiplicity of societies, but lack of real organization, there as here, made the influence of the technical men almost negligible in comparison with organized labor and entrenched law and politics. There are 37 engineering societies in Italy, all provincial or local.

Capt. Tuccimei served four years in the Italian Artillery, on the Austrian Front. Many other engineers were in the army. As they met from time to time and discussed their situation, they perceived that their weakness in peace and in war as an element of the nation which should have been strongly influential because of their knowledge, was due to lack of an organization which could speak with the power of numbers and unity of purpose. This weakness not only caused loss to the nation, but resulted in low appreciation of the technical man's value to society and consequent inadequate compensation for his services.

Out of the informal conferences of civilian engineers in the army grew a determination to combine all the engineers and architects into one great National association. After due preparation, the scheme was launched in April, 1919, throughout the country by a speaking campaign before the societies of engineers in the principal cities and organization was completed in May. Definite proposals were made, also, to the

existing provincial and local societies. By September, the Associazione Nazionale degli Ingegneri Italiani had 4 000 members; it expects to have in its ranks practically all of the 10 000 professional engineers and architects in Italy. Only graduates of universities are eligible to membership. The Association's aims are: Larger and better service to the Nation and to the community; greater influence for technical men; more adequate compensation for their services, and the direction of technical projects by technical men as employers and not, as heretofore, as employees, especially for after-war reconstruction work.

Federation of existing societies was attempted, but found impracticable because of the traditions, pride of existence and rivalries which they had accumulated in their thirty to fifty years, or more, of life. It is expected that the old societies will all become parts of the new Association by merging their membership and accepting the constitution and by-laws of the Association, of which they will be sections.

Engineers in the 1920 United States Census

As a result of Engineering Council's request to the Director of the Census, the National Service Committee has been successful in effecting a reclassification of engineers so that all technical engineers will be listed as such, separately and distinctly from the non-technical engineers. Thus, the next census will bring an enumeration of all technical engineers together as one unit under the main headings of Civil, Mechanical, Electrical and Mining. Architects will also be enumerated separately.

The Steel Basing Point

As a result of further hearings before the Federal Trade Commission, it has been conceded that there will be no abolition of the long established practice of using Pittsburgh as a steel basing point. The interests that favor a single price basing point, notably the Western Association of Rolled Steel Consumers, base their claim on the allegation that the practice of using Pittsburgh is in violation of the Clayton Act. This group has attempted to show that they pay a fictitious rate on fictitious transportation from Pittsburgh on steel produced through the Western District and for this reason they claim that they are unable to compete in the Eastern market, whereas the Eastern fabricators can place their products in the Chicago market on an even competitive basis. They declare that the public was taxed $30 000 000 a year through increased prices of manufactured steel.

Counsel for the Steel Corporation showed that since Chicago producers can only supply one-half of the Chicago demand, the Pittsburgh price must dominate since it supplies the other half. There would be

no advantage to the Chicago producers in selling at less than the Pittsburgh price when they could not profit by any extra demand so created. They naturally sell at the market price, which is the Pittsburgh level. When producers can supply all the requirements of their own territory, the Pittsburgh basing point will cease as a result of natural laws. Other important steel producers have given testimony substantiating these claims.

Highway Legislation

The original bill proposing to create a National highway system controlled by a Federal Highway Commission, which was proposed by Senator Townsend, has been practically abandoned because of the opposition which has developed. It is now believed that any plan for National highways constructed directly by the Federal Government will be unpopular with the States because only a limited portion of the State will be benefited directly by such highways. Further, the Government with its road building activities would be in competition with the States and the counties. It is believed that it will be easier for the Federal Government to hold the States up to a standard rather than to attempt to maintain the standard through its own work.

Another highway bill which proposes a National Highway Department and Highway Commission has been introduced into the House, which aims to do away with the defects which have become apparent in the Townsend bill. It will bring the control of highway work more closely under the control of the States, at the same time giving enough Federal supervision to insure co-ordination and standardization in the work. The States are to be divided into ten regional areas with corresponding Regional Congresses having direct control of the work in their region, but under the general direction of the National Highway Commission.

For the purpose of carrying out the provisions of this new act and as an initial appropriation for the creation of a National Department of Highways, the new bill proposes to appropriate $10 000 000. The Secretary of Highways would receive $12 000 per year, and each National Highway Commissioner would receive $6 000 per year.

Estimates for Public Works—Fiscal Year 1920

The Secretary of the Treasury has approved and forwarded to Congress estimates for next year which total the unusually large sum of $283 921 810. The appropriations for public works during the fiscal year 1920 total $93 872 092. The estimates for work of particular interest to engineers and constructors are as follows:

Construction of Government buildings, including purchase of sites, $1 332 775; marine hospitals and quarantine stations, $5 204 621; forti-

fications, $117 793 330; military posts, $14 225 251; rivers and harbors, $53 659 265; Navy yards and stations, $20 606 000; Panama Canal construction and maintenance, $18 245 391; depots for coal and other fuels, $2 335 000; Reclamation Service, $20 134 000; $725 000 special appropriation for a fuel inspection system; $1 865 880 for the Bureau of Mines; $2 592 920 for the Geological Survey, and $3 000 000 (approximately) for the Bureau of Standards.

Continuance of Construction Division

At the time hearings were being held on the subject of Army reorganization, the Chairman of the National Service Committee of Engineering Council addressed the Military Affairs Committee of both Houses and Gen. Pershing, directing their attention to the splendid record of the Construction Division, and urged that this Division be continued in substantially its present form so that it will be enabled to carry on the work that has been started, in the same efficient manner. Replies from the Chairmen of both Committees indicated that they realized the value of the Construction Division under its present organization and showed that they personally were in favor of maintaining this Division intact.

There is still a good chance that the Military Affairs Committees of both Houses will recognize it as a separate corps. The officials of the Construction Division and practically all civil engineers who have had work with the Division in the various parts of the country desire that such action be taken. It is the general belief that the efficiency of the Construction Division will be impaired if it is returned to the Quartermaster General's Department or made a part of the Engineer Corps.

The points made against incorporating the Construction Division in the Engineer Corps or returning it to the Quartermaster's Department were that engineers are the first to be sent to the front, whereas the duties of the Construction Division are at training camps, supply depots, etc., some distance from the actual fighting. Thus, it would be far removed from its administration, beside which such men do not have the kind of technical training that is required in the construction work. If the Construction Division was returned to the Quartermaster Department it would soon swallow up that department, especially if the proposed construction programme of the Army is carried out.

The bill proposed by the General Staff is dead from a legislative standpoint, as is the Dent bill and other drafts made along the lines of the General Staff bill. The Military Affairs Committees are drafting entirely new Army reorganization bills which it is expected will be introduced in the respective Houses shortly.

The Movement for a Mental Hygiene of Industry

In February, 1919, Engineering Foundation undertook to support a limited study by Dr. E. E. Southard, Director, Massachusetts State Psychiatric Institute, of mentally abnormal persons in industry. The Massachusetts Department of Mental Diseases, The National Committee for Mental Hygiene, and the Permanent Charity Fund, of Boston, have co-operated. The preliminary paper of a series, an introductory statement on the nature of this study, prepared by Dr. Southard, has been published substantially in full in the February issue of *Industrial Management* and in the January issue of *Mental Hygiene* under the title "The Movement for a Mental Hygiene of Industry". Engineering Foundation has reserved the rights of publication.

This new development in the analysis of certain definite modern tendencies in industrial relations is treated by Dr. Southard from the basis of the achievements of psychologists, physicians and social workers during the War. He defines "mental hygiene" as a term coming into general use to cover the expert activities of pyschiatrists (medical men interested in problems of mental disease, including the mildest forms of temperamental deviation) and gives, as the keynote of this systematic attack on industrial personnel problems by means of mental hygienic data and methods, the pooling and co-operative combination of expert engineering interest with expert medical, psychological and sociological interests. He asks why industrial managers should not seek the aid of (*a*) those who can measure mental capacities, (*b*) those who are specialists in temperament, and (*c*) others capable of helping to trace out the actual situation, for example, in labor turnover.

The other papers of the series are to be entitled, as follows: "Specifications for Clinics to Demonstrate to Employment Managers Certain Useful Points in Character and Temperament"; "Analysis of a Further Series of Psychopathic Employees, with an Account of Success and Failure in Their Placement"; "Bibliography with Comment"; "The Utility in Industrial Problems of the Modern Specialist in Grievances", and "A Comparison of Tendencies to Violence Shown in Industry with Like Tendencies in the Insane".

Engineering Foundation Appeals for Funds

A letter from W. F. M. Goss, Chairman of The Engineering Foundation, calls attention to the Progress Report of the Foundation Board, and appeals to the Founder Societies to help increase the endowment fund of \$300 000, donated by Ambrose Swasey, to at least \$500 000. He believes the Foundation should look forward to a growth in its endowment at a rate of not less than a half million dollars a year for the next five years, and asks whether there are not other engineers, like Mr. Swasey, who will find satisfaction in having a part in the upbuild-

ing of a permanent organization for the advancement of the profession of engineering and the good of mankind. He outlines briefly the Foundation's work, as follows:

"It contributed, for a considerable period, its full strength to the support of the National Research Council, an organization then in its formative period and without support, and which now commands the assistance of many different agencies and functions in many different fields.

"It collaborated with the National Research Council in working out a basis for future co-operation which now seems to assure the harmonious development of both organizations.

"When the nation was at war, it conducted tests in co-operation with the Committee on Submarine Detection, to determine the value of a veil of spray in reducing the visibility of ships at sea, with results which have been formally reported.

"As represented by Messrs. Woodard, Porter and Townley, it conducted a careful inquiry concerning the practicability and advisability of establishing a hydraulic station for testing large water wheels.

"It formulated a proposal to the several Founder Societies to undertake along the broadest possible lines, with the aid of highly qualified experts and in co-operation with all agencies willing to help, a study of engineering society organization for the purpose of developing a possible procedure or series of procedures of such evident merit that they would appeal to those who are likely to be most interested.

"It is now conducting under the direction of Professors Guido Marx and Lawrence E. Carter, an investigation concerning the wear of gears.

"It is now conducting under the general direction of Dr. Michael I. Pupin, experiments covering methods proposed for the secret directive control of wireless communication.

"It is now conducting in co-operation with Mr. Clemens Herschel, experiments covering certain unsolved factors in the behavior of water and other liquids in passing over weirs.

"It is now conducting in co-operation with Dr. E. E. Southard, a preliminary investigation as to the part played by mental abnormalities in industry.

"It is now assisting the Division of Engineering, National Research Council, in a series of preliminary investigations concerning the desirability of researches along several different specific fields of activity.

"It is now co-operating with the University of Illinois, as represented by Professor H. F. Moore, in advancing with the utmost rapidity, the important researches which he has in hand on the Fatigue Phenomena of Metals."

Agreement for Research in Fatigue of Metals

In order to carry out the programme for a co-operative investigation of the fatigue phenomena of metals,* articles of agreement have been entered into between the University of Illinois, the Engineering Foundation, and the National Research Council. The agreement is executed for a period of two years beginning November 1st, 1919, and provides that the University will delegate Prof. H. F. Moore, or some other

* *Proceedings,* Am. Soc. C. E., Oct.–Nov.–Dec., 1919, p. 956.

competent person should his connection with the University cease, to supervise and direct all experimental work and the computation and reduction of all results obtained, together with the placing of these data into form for presentation.

To finance this work, Engineering Foundation paid $9 000 to the University on November 15th, 1919, and is to pay $3 000 quarterly up to and including August 15th, 1921. The necessary special apparatus may be purchased and shall remain the property of Engineering Foundation until disposed of by its direction. The Committee on the Fatigue Phenomena of Metals of the National Research Council shall constitute the Advisory Committee in developing the test programme and the conduct of the investigation, although the actual conduct of the tests shall be under the control of the Engineering Experiment Station of the University, and the latter is to have the right to publish the results as a bulletin of the Station. In addition, the Station is to prepare a brief, comprehensive statement regarding the investigation, suitable for publication in the journals of the Engineering Societies.

Provision is made to allow publication by the Engineering Foundation and the National Research Council in case the University is unwilling to proceed with the publication of the results within a reasonable time. The manuscript is to be approved by the Advisory Committee, the Engineering Foundation, and the National Research Council, except that the University can proceed with the publication if this approval is not given within a reasonable time. Research assistants, etc., are to be employed by the University and paid out of the fund provided by the Foundation, payments by the latter to be deferred, however, if progress and disbursements are not as rapid as the quarterly rate of payment agreed upon.

Engineering Societies Employment Bureau

A statistical statement of the activities of the Engineering Societies Employment Bureau, of which Walter V. Brown is Manager, shows that during the year from December 1st, 1918, to December 1st, 1919, a total of 5 377 men were registered and of these 1 256 are reported as placed. The total number of positions registered as available was 2 495, and 502 are reported as open, the report being dated November, 1919. The distribution among the four Founder Societies is given as follows:

Society	Registered	Placed
Civil Engineers	507	104
Mining Engineers	279	60
Mechanical Engineers	975	265
Electrical Engineers	521	105
Total Members	2 282	534
Non-members	3 095	722
Grand Total	5 377	1 256

It is pointed out that the figures given for men placed are based upon the best obtainable data at hand, are approximate only, and are much lower than they should be because of the great difficulty of getting reports of placements.

The governing bodies of the four Founder Societies have directed that the appropriation for the year 1920 for employment activities be separated from the appropriation for Engineering Council, and that the employment activities be conducted directly by the Societies under the supervision of their respective secretaries, in accordance with the practice in force for many years prior to the war.

Engineering Journals Adopt Standard Magazine Size

With the issues of January, 1920, two of the Founder Societies—the American Institute of Electrical Engineers and the American Institute of Mining and Metallurgical Engineers—have enlarged their monthly publications to standard 9 by 12-in. magazine size and changed their policy in presenting a record of Society activities. All the Founder Societies except the Civil Engineers have now adopted the common standard, and are accepting advertising as a substantial addition to the income to help defray the cost of publication.

In *Mining and Metallurgy,* the technical papers are inserted as pamphlets 6 by 9 in. in size, numbered as sections to comply with the postal regulations. These papers can then easily be filed for reference or for binding with other material on any given subject. The new form gives opportunity properly to use and display the many valuable papers presented at the meetings of Local Sections and not becoming part of the *Transactions.* Abstracts from important papers in current periodicals, domestic and foreign, are made a feature of the publication, which in its first number has set a high standard for the future.

The *Journal* of the American Institute of Electrical Engineers, formerly its *Proceedings,* in its new size and dress has also set a high standard, and is one result of the work of the Institute's Committee on Development, based upon the response of the membership to the Committee's request for suggestions. The new *Journal* will include not only the material similar to that heretofore published and consisting principally of engineering and theoretical papers and discussions, but additional matter relating to progress in the art of electrical engineering selected with the object of publishing in each issue something that will appeal to each reader.

Many other professional Societies have adopted substantially the same size, including the Institution of Electrical Engineers of Great Britain, the Engineering Institute of Canada, the American Chemical Society, and the Society of Automotive Engineers, as well as the American Society of Mechanical Engineers.

Engineers' Club of Lansing, Mich.

Following a meeting called on October 29th, 1919, the engineers of Lansing, Mich., formed the Engineers' Club of Lansing, which has met five times during the Fall, with an average attendance of 75. The membership is not limited to members of the Founder Societies, but embraces all grades of engineers. It is hoped that the organization will develop along the lines recommended by the Committee on Development of the Society. The following officers were elected for the coming year:

President, O. E. Eckert, Assoc. M. Am. Soc. C. E., City Engineer, Lansing; Vice-President, C. E. Bement, Vice-President and General Manager, Novo Engine Company, Lansing; Secretary-Treasurer, F. L. Radford, Assistant Engineer, Reo Motor Car Company, Lansing; Directors, E. D. Rich, M. Am. Soc. C. E., State Sanitary Engineer, and G. W. Bissell, Dean of Engineering, Michigan Agricultural College, Lansing.

American Engineering Standards Committee

At the annual meeting of the American Engineering Standards Committee, A. A. Stevenson was elected Chairman and G. C. Stone, Vice-Chairman for the coming year. Dr. P. G. Agnew, formerly Assistant Physicist of the United States Bureau of Standards, accepted the position of Secretary, his duties to begin on December 15th, 1919. The resignation of the former Chairman, Comfort A. Adams was accepted "with many regrets and with heartfelt thanks for the excellent way in which he had guided the affairs of the Committee since its inception". The further hope was expressed that his new duties with The National Research Council as Chairman of the Division of Engineering would permit continued co-operation in the future.

Following the reading of a letter from the Association of American Steel Manufacturers requesting the appointment of sponsor bodies for the standardization of rolled structural sections, the Committee voted: "that the American Society of Civil Engineers, The Association of American Steel Manufacturers, the American Railway Association and the Society of Naval Architects and Marine Engineers be invited to accept sponsorship for the formulation of standards of rolled structural sections."

EUROPEAN NOTES

The following notes relative to reconstruction, etc., in Belgium and France, and industrial progress, etc., in Great Britain and elsewhere, have been contributed by W. E. Woolley, Assoc. M. Am. Soc. C. E., of London, England, who is also a Corresponding Member of the Association of Liége (Belgium) Architects.

Additional Organizations for Engineers and Architects, England

An additional society for engineers, called the "Society of Technical Engineers", was founded during the Late War, in London. All technically trained engineers, whether civil, mechanical, electrical, municipal, etc. are eligible for membership. The main object of the society appears to be to protect the interests of the technically trained professional engineer.

Two additional architectural organizations have lately sprung into existence, one of them, the "Official Architects' Association", held its first general meeting on December 1st, 1919, with Mr. W. E. Riley, late Superintending Architect, London County Council, as its first president. The Association is formed to serve a longfelt want by architects engaged in official positions. The second organization, "The Architects' and Surveyors' Assistants' Professional Union", at a meeting held on December 5th, 1919, adopted its constitution and rules, as prepared by the London Executive Committee. It is, in reality, a welfare union of assistants.

Steel Houses

Mr. Bonar Law recently stated that the British Government was considering the practicability of the erection of steel houses, and that experiments of this nature are to be carried out.

The Tunnel Under the British Channel

Sir Arthur Fell declared to the Aldwych Club, that the War Department is favorable to the construction of the tunnel under the Channel, although it does not wish to declare itself to Parliament.

He foresees the daily departure of an express from Charing Cross (London) to Bagdad, about fifteen years hence.

Exchange of Students

It has been announced in *La Metropole,* Antwerp, that there is a proposal for an exchange between American and Belgian students, the former coming to make their studies in Belgium, the latter to enter the Universities of Princeton, Harvard, Johns Hopkins, Stanford, etc. This has been done through the initiative of H. C. Hoover, M. Am. Soc. C. E., who has formed in the United States a commission to devote its attention to these exchanges. A committee has been formed likewise in Brussels, under the presidency of M. Franqui, Secretary of State.

About 200 American students have asked to come to Belgium. A call will be sent to the Belgian Universities for those who would wish to complete their studies in America.

Reconstruction in the Devastated Regions

To the list of community stores finally established should be added those of Avelghem, Surice, Nieuport, and Westende. Many other stores will be established, notably in Dixmude and in the south of the Province of Luxembourg.

The purchases of wood from the Service of Recuperation are proceeding. These materials will be given to the Office of Devastated Regions at an average low price of 150 francs per cu. m. taken from the timber yard; 140 000 cu. m. are already acquired and it is probable that this quantity may be increased to 200 000 cu. m. In addition to the wood, the Service of Recuperation has ceded a large quantity of iron of all kinds at the price of about 350 francs per ton. The community stores can, from the present time, fix the quantities of the materials which they wish to recover.

The Office of Devastated Regions is assured also the supply of at least 8 000 000 tiles at much lower prices than those on the market.

French Society of Civil Engineers

At a meeting of French engineers resident in England, held on November 24th, 1919, at the Royal Society of Arts, Adelphi Street, London, a British Section of the "Societe des Ingenieurs Civils de France" was inaugurated. This promises to be a great success. Representatives of nearly all the British Engineering Societies, and other Scientific Societies were present. A sessional programme has been drawn up, and it is likely that the proceedings will be bi-lingual. C. H. Wordingham, C. B. E., M. Inst. C. E., etc., is Honorary President, and T. J. Gueritte, President.

BRIEF NOTES

As a result of the recommendations of the Committee on Development of the American Institute of Electrical Engineers and a petition presented by over 100 New York members to its Board of Directors, a special meeting was called on December 10th, 1919, and a New York Section of the Institute was organized. By-laws similar to those of the other thirty-four Sections of the Institute were adopted.

In view of the great part the Universities of the United States and Great Britain are taking, and must increasingly continue to take, in the problems of reconstruction, the following passage from "Joan and Peter", by H. G. Wells, is interesting: "Instead of the University *passant regardant*, we want the University *militant*. We want Universities all round and about the world, associated, working to a common end, drawing together all the best minds and the finest wills, a myriad of multi-colored threads, into one common web of a world."

The *Wall Street Journal* announces that the automobile output in France in 1920 will reach 200 000 cars, compared with 30 000 in 1914, exclusive of commercial trucks, and states that the supply cannot overtake the demand even at the present rate of production and after absorption of 150 000 American Army cars.

Correspondence from London states that Great Britain has realized $555 000 000 from the sale of surplus stores and property since the armistice.

The Post Office Department states that all load-carrying airplane records were broken on December 2d, 1919, when a twin-motor De Haviland-4 plane, devised by and manufactured for the Department, covered the distance between the air mail field at Washington and that at Belmont Park, New York, a distance of 218 miles, in 1 hour, 34 min., with a mail load of nearly 30 000 letters weighing 630 lb.

It is announced from London that British salaried professional men are forming a federation designed to insure them the increased income and other benefits which other workers have gained through trade unions. Industrial workers have received wage increases amounting to 130% or 140% during the war, while the cost of living has been increased 128%, according to organizers of the Professional Workers' Federation.

The Secretary of War directs that the Engineer Corps shall be responsible for the preparation and production of aerial route maps and will be guided in such work by the technical requirements of the Air Service. The Air Service is responsible for securing and furnishing such aerial data as may be needed, and the two services are to confer in working out principles and methods of producing aerial route maps.

At a hearing by the Joint Congressional Commission on Reclassification of Salaries, a committee representing Federal employees disclosed that the "turnover" in personnel among the scientific and technical workers of the Government amounted in some offices to 100% a year. More than 6 000 technical and scientific workers in the Government service at Washington were represented by the Committee.

The Director of Sales of the U. S. War Department, carrying out the desire of the Government to assist in the rehabilitation of French industries, especially those located in devastated regions of France, has entered into contract with the French Republic, under the terms of which the French Government is permitted to purchase $25 000 000 worth of machine tools from surplus stocks of such tools held by the War Department in the United States. The French Government is to pay for such machine tools as it may purchase in ten-year 5% bonds of the French Republic which, at maturity, are payable in dollars at Washington in the gold coin of the United States.

The U. S. Geological Survey states that several factors have combined to put added emphasis on the country's need of an adequate large-scale map of its whole territory. With nearly 60% of the area of the country totally unmapped, and with the Geological Survey, the largest mapping organization in the country, surveying only about 40% of the area in 40 years, the logical demand is for more speed. If these maps are to serve their full purpose in promoting national development, the whole country should be mapped within the next decade. The estimated cost of this mapping programme is $40 000 000, including costs of revising the older surveys.

The Joint Congressional Commission on Reclassification of Salaries announced on January 5th, 1920, that the permanent tribunal to adjust wages and working conditions of Government employees in Washington will be the Civil Service Commission. It was also stated that it will recommend that the Commission be enlarged and that the reclassification system be extended to include the 500 000 Government employees.

Fire threatened to destroy the New York Engineers' Club on the morning of December 12th, 1919. The 350 members and guests sleeping in the building were awakened and assembled on the lower floors. Although the fire was confined to the three upper floors, smoke and water caused considerable damage.

A dinner in honor of Charles Eugene Schneider, of France, was given by the Mining and Metallurgical Society of America at the Biltmore Hotel, New York City, and he was presented with the gold medal of the Society by H. H. Knox, President, for distinguished services in ferrous metallurgy. Mr. Schneider, as President of the Creusot Works, manufactured the famous French 75's. He is the first foreigner to receive the Mining and Metallurgical Society Medal. The first medal was awarded in 1914 to Herbert C. Hoover, M. Am. Soc. C. E., and Mrs. Hoover, for their translation of "De Re Metallica".

At the last Annual Meeting of the American Society of Mechanical Engineers the following creed, which was formulated by the New York Section, was adopted: "Every important enterprise must adopt competent productive management, unbiased by special privilege of capital or of labor, and disputes must be submitted to authorities based upon intrinsic law. Credit capital represents the productive ability of the community and should be administered with the sole view to the economy of productive power, that is, it should be granted only to those who are able to render valuable service."

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, New Year's Day, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 6 P. M.

FUTURE MEETINGS

February 4th, 1920.—8.30 P. M.—A regular business meeting will be held, and a paper by James F. Sanborn and M. E. Zipser, Associate Members, Am. Soc. C. E., entitled "Grouting Operations, Catskill Water Supply", will be presented for discussion.

This paper is printed in this number of *Proceedings*.

February 18th, 1920.—8.30 P. M.—A meeting will be held on this evening as usual, and announcement of the programme which is in the hands of the Programme Committee for Second Meeting of Each Month, will be made later.

March 3d, 1920.—8.30 P. M.—This will be a regular business meeting. A paper by Frank G. Jonah, M. Am. Soc. C. E., entitled "The 'Light Railways' of the Battle Front in France," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

March 17th, 1920.—8.30 P. M.—The usual meeting will be held, and announcement of the subject and speaker will be made later.

ROLL OF HONOR

Now that the war is over, the monthly publication in *Proceedings* of the Roll of Honor has been discontinued. It is planned to publish in the Year Book for 1920, for permanent record, a list of all the members of the American Society of Civil Engineers whose names have appeared on this list.

ENGINEERING SOCIETIES EMPLOYMENT BUREAU

Engineering Societies Employment Bureau, established December 1st, 1918, as an activity of Engineering Council, is managed by a board made up of the Secretaries of the four Founder Societies, funds for its maintenance being provided by these Societies. The work of the Bureau since its inception has been largely in the line of securing employment for men retiring from government war service. Members of the American Society of Civil Engineers who desire to register with this Bureau should apply for further information, registration forms, etc., to Walter V. Brown, Manager, Engineering Societies Employment Bureau, First Floor, Engineering Societies Building, 29 West 39th Street, New York City.

SEARCHES IN THE LIBRARY

As the Library of the American Society of Civil Engineers has been merged in the Engineering Societies Library, requests for searches, copies, translations, etc., should be addressed to the Director, Engineering Societies Library, 29 West 39th Street, New York City, who will gladly give information concerning the charges for the various kinds of service. A more comprehensive statement in regard to this matter will be found on page 21 of the Year Book for 1919.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion will be published as heretofore in *Proceedings*, and set down for presentation to a future meeting of the Society, and, on these, oral discussion, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 35 of the Year Book for 1919.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association, Organized 1905.

M. M. O'Shaughnessy, President; Nathan A. Bowers, Secretary-Treasurer, 502 Rialto Building, San Francisco, Cal.

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Engineers' Club, 57 Post Street, on the third Tuesday of February,

April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at noon, every Wednesday, at the Engineers' Club, where special tables are reserved for members and guests of the Association.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

(Abstract of Minutes of Meetings)

October 21st, 1919.—The meeting was called to order at the Engineers' Club; President Schneider in the chair; Nathan A. Bowers, Secretary; and present, also, 87 members and guests.

The Secretary presented a communication from Mr. A. E. Chandler, former President of the California State Water Commission, in reply to the letter from the Board of Directors of the Association expressing appreciation of his services as Water Commissioner.

A letter was also presented from Capt. Milo H. Brinkley announcing his discharge from Army service, his appointment as Valuation Analyst with the Interstate Commerce Commission, and his resignation as a member of the Association.

President Schneider reported as to the success of the dinner given to Mr. Herbert C. Hoover, under the auspices of the Joint Council of Engineering Societies of San Francisco, at which about 325 were present.

Mr. H. L. Haehl reported briefly on the last session of the Committee on Development, stating that its Final Report had been presented to the Board of Direction of the Society.

Mr. H. J. Brunnier, for the Membership Committee, urged the co-operation of the membership in securing new members for the Society and for the Association.

Mr. E. T. Thurston presented the need for prompt action in regard to contributions to the fund in support of the proposed National Department of Public Works being collected from the members of the Association.

Mr. Jerome Newman, for the Committee co-operating with the State Civil Service Commission, reported that the Commission was working on the reclassification of the engineering branches and that when the work was completed it had been planned to have a joint meeting of engineering society committees to consider the matter further.

Reporting for the Entertainment Committee, President Schneider described the trip to the California-Hawaiian Sugar Company's plant and asked for suggestions as to other field trips.

Professor Charles D. Marx stated that the report of the Committee on Development presented to the Board of Direction of the Society, had been referred to a Special Committee of the Board and that a final report was expected to be in the hands of the members of the Society by November 15th.

Secretary Bowers who had just returned from a trip to the Northwest, reported on what he had found of interest to the Association in the activities of the Engineering Societies of Portland, Seattle, Vancouver, and Spokane, and, relative to improving the work of the Asso-

ciation, suggested that at least one member of the Board of Directors attend the Wednesday luncheons, that members of the Association bring ideas for discussion to those luncheons, and that a little time be given at the meetings of the Association to plan for its general improvement.

President Schneider introduced Mr. M. M. O'Shaughnessy who addressed the meeting on "The Hetch Hetchy Project", in the course of which he described the engineer's side of the work from the beginning.

On motion, duly seconded, a vote of thanks was extended to Mr. O'Shaughnessy for his address.

Adjourned.

December 16th, 1919.—The Fifteenth Annual Meeting of the Association was held at the Engineers' Club; President Schneider in the chair; Nathan A. Bowers, Secretary; and present, also, 90 members and guests.

Letters were presented from several members of the Association who have retained their membership although they have removed from San Francisco.

The Secretary read a letter transmitted recently by the Joint Council of Engineering Societies of San Francisco to the Board of Supervisors, which contained the following resolution:

"*Resolved:* That the Joint Council of Engineering Societies of San Francisco, representing over 1 100 members of the Engineering Profession, publicly disapproves, and repudiates, the recent action of the Board of Supervisors of the City and County of San Francisco, criticizing the legal processes of our Government rightfully invoked to prevent the general strike of the bituminous coal miners; and

"*Further,* That the said Board of Supervisors be hereby reminded that it has exceeded its authority in attempting to take public action on a matter plainly without the duties for which it has been created."

Extracts from communications and bulletins from Engineering Council and from its National Service Committee in Washington, relative to its various activities, were presented by the Secretary.

The report of the Treasurer for 1919 was presented, and the Secretary explained briefly the causes of the increased expenditure, such as printing, etc.

President Schneider reported that at a recent meeting of the Board of Directors of the Association it was decided that hereafter the space allotted in *Proceedings* to the abstract of the paper of the evening should not exceed one or two paragraphs, the remaining space to be devoted to business reports, Association affairs, etc.

In presenting his report, the Secretary stated that evidence of the interest of the membership in the Association was noticeable, that the net gain in membership in 1919 was 11, and that the total membership is 211.

A letter relative to the place for holding the 1920 Annual Convention of the Society, from Mr. Harry Hawgood, Director from District No. 11, was read, and, in reply, the following resolution of the Board of Directors, on motion, duly seconded, was unanimously adopted by the meeting and ordered sent to Secretary Hunt:

"*Whereas,* The next Annual Convention of the American Society of Civil Engineers is to be held in District 11, and

"*Whereas,* The larger part of the membership of Districts 10, 11, 12, and 13 is included in the Pacific Coast States of Washington, Oregon, and California,

"*Resolved,* That the San Francisco Association of Members of the American Society of Civil Engineers assembled in annual meeting requests that the Annual Convention of 1920 be held in Los Angeles, believing that this will enable a large number of Pacific Coast members to attend, will afford an opportunity for delegates from the East to meet members from the Pacific Coast and will promote closer relations between the different sections of the membership."

Mr. Jerome Newman, for the Civil Service Committee, reported progress in connection with its work with the State Civil Service Commission.

Mr. C. E. Grunsky reported that Professor Charles D. Marx had been appointed as Chairman of a State Committee to collect funds to further the proposed organization of a National Department of Public Works, and asked for contributions.

President Schneider discharged with thanks the Committees on Membership, Entertainment, Public Relations, and Development.

Professor Marx reviewed briefly the recent activities of the Joint Council of Engineering Societies of San Francisco for the benefit of the membership.

It was announced that a special meeting of the Association would be held at the Engineers Club on January 20th, 1920, to discuss with O E. Meinzer, Chief of the Ground-Water Division, of the U. S. Geological Survey, a glossary of terms pertaining to ground-water, at which Mr. Charles H. Lee would preside.

Plans for an Engineering Building in San Francisco were discussed briefly by Mr. E. C. Hutchinson.

President Schneider appointed Messrs. Lee, McWethy, Bolin, Holly, and Saph, as tellers to canvass the ballot for officers for the ensuing year. The following officers were elected: President, M. M. O'Shaughnessy; First Vice-President, F. E. Muhs; and Second Vice-President, W. L. Huber.

Mr. Francis Betts Smith presented a paper entitled "Building the Pearl Harbor Dry Dock", illustrating his description of the work with lantern slides. The subject was discussed further by Messrs. S. G. Hindes, J. D. Galloway, and others.

Adjourned.

Colorado Association, Organized 1908.

W. C. Huntington, President; A. N. Miller, Secretary-Treasurer, 1400 West Colfax Avenue, Denver, Colo.

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary. The meetings are usually preceded by an

informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesday, at 12.30 P. M., at Daniels and Fisher's.

Visiting members are urged to attend the meetings and luncheons.

Atlanta Association, Organized 1912.

V. H. Kriegshaber, President; Howard L. Stillwell, Secretary-Treasurer, 533 Trust Co. of Georgia Bldg., Care, Southeastern Underwriters' Association, Atlanta, Ga.

Informal luncheons are held for members of the Association on the last Monday of each month, at 12.30 P. M., to which visiting members of the American Society of Civil Engineers will be welcomed. The place is not fixed, but this information will be furnished on application to the Secretary.

Baltimore Association, Organized 1914.

H. G. Perring, President; Charles J. Tilden, Secretary-Treasurer, The Johns Hopkins University, Baltimore, Md.

Cleveland Association, Organized 1914.

W. P. Brown, President; George H. Tinker, Secretary-Treasurer, 516 Columbia Building, Cleveland, Ohio.

The regular meetings of the Association are held on the second Wednesday of each month, at 12.15 P. M., in the Rooms of the Electrical League, on the Fourteenth Floor of the Statler Hotel. Luncheon is served at these meetings, and visiting members are invited to attend.

(Abstract of Minutes of Meeting)

December 10th, 1919.—The meeting was called to order at the rooms of the Cleveland Engineering Society at 12.15 P. M.; President Richards in the chair; George H. Tinker, Secretary; and present, also, 16 members.

The minutes of the meeting of November 11th, 1919, were read and approved.

Messrs. A. V. Ruggles, C. G. French, and A. F. Blaser were appointed as a Nominating Committee by President Richards.

The Secretary presented a communication from the Ohio Association of Technical Societies in reference to a proposed schedule of salaries for engineering employees in the State Civil Service. On motion, duly seconded, it was decided that the schedule was too low and should be the minimum considered at the present time.

The Committee appointed to report on the schedule of minimum fees for civil engineers adopted by the Engineers of Mahoning Valley, submitted a schedule of minimum fees for practicing engineers. On motion, duly seconded, the schedule was approved.

The Nominating Committee reported the following recommendations for officers for 1920: For President, W. P. Brown; Vice-President, J. E. A. Moore; and Secretary-Treasurer, George H. Tinker; and, on motion, duly seconded, the nominees were declared elected.

On motion, duly seconded, it was decided that the Director of the Association on the Board of the Association of Ohio Technical Societies should be paid seven cents a mile to cover expenses when attending Board meetings.

On motion, duly seconded, the dues for 1920 were fixed at $2.00.

Adjourned.

Connecticut Association, Organized 1919.

C. M. Saville, President; R. J. Ross, Secretary, Municipal Building, Hartford, Conn.

The Annual Meeting of the Association is held in April. The time and place of other meetings are not fixed, but this information will be furnished on application to the Secretary.

Detroit Association, Organized 1916.

T. A. Leisen, President; Clarence W. Hubbell, Secretary, 2348 Penobscot Building, Detroit, Mich.

The regular meetings of the Association are held on the second Friday of December, April, and October, the last being the Annual Meeting.

District of Columbia Association, Organized 1916.

David S. Carll, President; James C. Van Wagenen, Secretary-Treasurer, 719 Fifteenth Street, N. W., Washington, D. C.

Duluth Association, Organized 1917.

G. A. Taylor, President; Walter G. Zimmermann, Secretary, Wolvin Building, Duluth, Minn.

The regular meetings of the Association are held at noon on the third Monday of each month (usually at the Kitchi Gammi Club), with luncheon, followed by a short business session and the reading of papers. Visiting members of the American Society of Civil Engineers can secure from the Secretary definite information relative to the meetings, at which they will be welcomed. The Annual Meeting is held on the third Monday in May.

Illinois Association, Organized 1916.

Albert Reichmann, President; W. D. Gerber, Secretary-Treasurer, 913 Chamber of Commerce, Chicago, Ill.

The regular meetings of the Association are held on the second Monday of March, June, September, and December, the last being the Annual Meeting. The hour and place of meetings are not fixed, but this information will be furnished on application to the Secretary.

Louisiana Association, Organized 1914.

Arsène Perrilliat, President; Eugene F. Delery, Secretary, 503 City Hall Annex, New Orleans, La.

The regular meetings of the Association are held at The Cabildo, New Orleans, La., on the first Monday of January, April, July, and October.

Nebraska Association, Organized 1917.

Clark E. Mickey, President; Homer V. Knouse, Secretary-Treasurer, 200 City Hall, Omaha, Nebr.

Regular meetings of the Association are held on the first Saturday of each month, except July and August, and at such places as may be appointed from time to time by the Executive Committee. The Annual Meeting is held in Lincoln, Nebr., on the second Friday in January.

Visiting members of the Society are especially urged to communicate with the Secretary when in the city.

Northwestern Association, Organized 1914.

Ralph D. Thomas, President; W. N. Jones, Secretary, City Engineer's Office, City Hall, Minneapolis, Minn.

The meetings of the Association are held bi-monthly, alternating between St. Paul and Minneapolis, on the third Friday of each month. Information as to the time and place of such meetings will be furnished on application to the Secretary.

Philadelphia Association, Organized 1913.

S. M. Swaab, President; Henry T. Shelley, Secretary, 416 City Hall, Philadelphia, Pa.

The regular meetings of the Association are held at the Engineers' Club of Philadelphia, 1317 Spruce Street, on the first Monday in January, April, and October, the last being the Annual Meeting. Special meetings will also be held during the winter, in order to provide an opportunity for members to take a more active part in the work of the Association.

(Abstract of Minutes of Meeting)

November 22d, 1919.—A special meeting of the Association was called to order at the Engineers' Club of Philadelphia, at 8 P. M.; President S. M. Swaab in the chair; H. T. Shelley, Secretary; and present, also, 60 members.

The meeting was called to review and discuss the Final Report of the Committee on Development of the Society, and to decide on definite action for its support.

The attention of the members was called to the tendency to subordinate the engineering features of public works to art and architecture, by Mr. F. Herbert Snow, who presented the following resolution which, on motion, duly seconded, was adopted by the meeting:

"*Whereas*, In the design and erection of bridges and other similar public structures, involving fundamentally strictly engineering questions, there is a widespread tendency to subordinate engineering to art and architecture, and

"*Whereas*, The formation of commissions and the selection of the personnel to have the direction of the execution of these works is now under consideration by state, county and municipal authorities,

"*Therefore be it Resolved*, That the Philadelphia Association of Members of the American Society of Civil Engineers earnestly directs

the attention of the Governor of the State, the County Commissioners and the Mayors of cities in the State to the fact that safety to human life and the proper expenditure of public funds require that the design and erection of such structures be under the responsible charge of competent and experienced civil engineers, especially skilled and trained for that class of work."

Mr. Richard L. Humphrey outlined the report of the Committee on Development and moved that an Executive Committee be appointed to conduct a campaign in behalf of the proposed development and that through such Committee teams of five or ten members, headed by a captain, be organized to make a personal canvass of the members of the Society and if possible secure their pledge to attend the Annual Meeting of the Society and support the report at that meeting and thereafter until a final vote on it is taken. On motion, duly seconded, the resolution was carried by a unanimous vote.

President Swaab appointed the following as members of the Executive Committee: Messrs. Benjamin Franklin, F. Herbert Snow, Samuel T. Wagner, Jonathan Jones, and Richard L. Humphrey, Chairman, with himself and Secretary Shelley as *ex-officio* members.

The Auditing Committee appointed to examine the accounts of the Secretary and Treasurer, submitted its report stating that the accounts were correct, and, on motion, duly seconded, the Committee was discharged with thanks.

The Secretary read a communication from the Engineers', Architects' and Constructors' Council, requesting the support of the Association for the bill to create a National Department of Public Works. On motion, duly seconded, it was decided to defer action on the request until the January meeting of the Association.

Adjourned.

Pittsburgh Association, Organized 1917.

Morris Knowles, President; Nathan Schein, Secretary-Treasurer, 426 City-County Building, Pittsburgh, Pa.

The Annual Meeting of the Association is held on the first Monday in October. The time and place of other meetings are not fixed, but this information will be furnished on application to the Secretary.

Portland (Ore.) Association, Organized 1913.

E. Burslem Thomson, President; C. P. Keyser, Secretary, 318 City Hall, Portland, Ore.

The Annual Meeting of the Association is held on the second Friday in January. Other meetings are called by the President and are usually convened on Friday evenings. The place is not fixed, but this information may be obtained on application to the Secretary. All members of the American Society of Civil Engineers are cordially invited to attend the meetings.

St. Louis Association, Organized 1888 (Constitution Approved by Board, 1914).

Edward E. Wall, President; C. W. S. Sammelman, Secretary-Treasurer, 300 City Hall, St. Louis, Mo.

The Annual Meeting of the Association, for the election of officers and for the transaction of business, is held on the fourth Monday in November. Two meetings each year, for the presentation and discussion of technical papers, are held in the Auditorium of the Engineers' Club of St. Louis and are open to members of the Associated Societies. Other "get-together" meetings are held regularly for dinner or luncheon on the fourth Monday of each month except July, August, and November.

San Diego Association, Organized 1915.

W. C. Earle, President; R. C. Wueste, Secretary-Treasurer, Bonita, Cal.

Seattle Association, Organized 1913.

L. M. Grant, President; G. A. Collins, Secretary, 1317 L. C. Smith Building, Seattle, Wash.

The regular meetings of the Association, with luncheon, are held at the Engineers' Club, Arctic Building, Third Avenue and Cherry Street, at 12.15 P. M., on the last Monday of each month. Informal luncheons are also held at 12.15 P. M., every Monday at the Engineers' Club.

Special evening meetings are held from time to time for the purpose of discussing important topics, and information concerning these meetings may be had by addressing the Secretary. All members in any grade of the American Society of Civil Engineers are cordially invited to attend the meetings when in the vicinity, and, if located in this District for any length of time, their membership in the Association will be appreciated.

Southern California Association, Organized 1914.

W. K. Barnard, President; Floyd G. Dessery, Secretary, 514 Central Building, Los Angeles, Cal.

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular monthly meetings on the second Wednesday of each month, the December meeting being the Annual Meeting.

Informal luncheons in connection with the Joint Technical Societies of Los Angeles are held at 12.15 P. M., every Thursday at the Broadway Department Store Café.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

(Abstract of Minutes of Meeting)

December 10th, 1919.—The Annual Meeting of the Association was called to order at the Jonathan Club, at 7.40 P. M.; Vice-President H. W. Dennis in the chair; F. G. Dessery, Secretary; and present, also, 60 members and guests.

On motion, duly seconded, the reading of the minutes of the meeting of November 12th, 1919, was omitted.

Chairman Moody, of the Committee on Co-operation of Federal Bureaus, gave a detailed verbal report of the extent of the work and

efforts of the Committee. On motion, duly seconded, the report was accepted and the Committee discharged.

Chairman Schwendener, of the Committee on Building Laws and Regulations, reported on the joint work of the Committee with a similar committee of the Chamber of Commerce. On motion, duly seconded, the report was accepted and the Committee discharged.

Chairman Irving, Association Member of the Joint Technical Societies Committee on Public Health and Sanitation, reported that a Final Report of the Committee would be made to the Board of County Supervisors on February 24th, 1920. On motion, duly seconded, the report was accepted and the Committee continued.

Mr. W. D. Smith, Association Member of the Joint Technical Societies Committee on City Planning, presented a progress report on the work of the Committee to date. On motion, duly seconded, the report was accepted and the Committee continued.

Vice-President Dennis, Permanent Chairman of the Committee on Ways and Means—1920 Convention, outlined briefly the work of this Committee to date.

In relation to holding the Annual Convention of 1920 in Los Angeles, Messrs. Allin and La Rue, of Pasadena, reported in regard to the interest of the Pasadena Board of Trade in the matter. Mr. Code reported on the apparent apathy of the Los Angeles Chamber of Commerce relative to the Convention and suggested that individual members of the Association underwrite $5 000 to cover the expenses in connection with it. The matter was also discussed by Messrs. Flaherty, Hawgood, Storrow, Michael, Mulholland, and Barnard, and, on motion, duly seconded, it was decided unanimously that Director Hawgood be instructed to bring the Annual Convention of the Society to Los Angeles in 1920.

Reports from the Sub-Committees of the Committee on Development of the Association were presented.

Mr. Bowen, Chairman of the Sub-Committee on External Relations, read the report of his Committee, which, on motion, duly seconded, was temporarily laid on the table, but, later, was referred back to the Committee.

The reports of the Sub-Committees on Technical Activities, Professor Michael, Chairman, on Internal Relations, Chairman Morris, and on Public Affairs, Chairman Moody, were read and, on motion, duly seconded, adopted.

On motion, duly seconded, the general report of the Committee on Development was approved, subject to the modifications recommended by the Sub-Committee.

Chairman Leeds, of the Committee on Universal Military Training, presented a report and Mr. Rockhold presented a Sub-Committee report. On motion, duly seconded, the report of the Committee was accepted, and it was ordered that the report of the Sub-Committttee be added to the Committee's report as an Appendix.

On motion, duly seconded, the Secretary was instructed to carry out the terms contained in the preliminary report of the Committee on Universal Military Training, which report was adopted at the meeting of November 12th, 1919.

Vice-President Dennis announced the death of Mr. George C. Adams, the father of Mr. E. L. Adams, member of the Association, and,

on motion, duly seconded, the Chairman appointed Messrs. Reed, E. R. Bowen, and E. T. Wheeler a committee to draft suitable resolutions to be spread upon the minutes of the Association and a copy to be sent to Mr. Adams.

The Annual Report of the Secretary for 1919 was read, and, on motion, duly seconded, the report was approved and a rising vote of thanks was extended to the Secretary for his work; a copy of the report was also ordered to be sent to the Society.

On motion, duly seconded, the following resolution was unanimously adopted:

"*Whereas,* Mr. George G. Anderson has ably served this Association as its President during the past year, and now at the completion of his term is retiring from office, and

"*Whereas,* He has been a most active member of the Committee on Development of the Parent Society and the Conference Committee, and has been a directing force in their deliberations, and

"*Whereas,* He has been uniformly and consistently alive to the welfare of the younger members of the profession, and

"*Whereas,* This Association, under his direction, has experienced the most successful year in its history. Now, therefore,

"*Be it Resolved,* That this Association hereby extends to Mr. Anderson its thanks and appreciation of his unselfish and tireless efforts in its behalf, and that these resolutions be spread upon the minutes of this Association and that a copy thereof be sent to Mr. Anderson."

In the absence of President Anderson, Vice-President Dennis read his valedictory address.

The Treasurer presented his Annual Report for 1919. On motion, duly seconded, the report was approved and adopted and Mr. Reed was thanked for his work as Treasurer of the Association.

The Secretary announced the election of the following officers for 1920: President, W. K. Barnard; Vice-Presidents, H. W. Dennis and R. J. Reed; Secretary, F. G. Dessery; and Treasurer, W. Woodard.

Vice-President Dennis introduced President Barnard who addressed the meeting briefly.

A general discussion on the imperative need of individual effort on behalf of the Annual Convention for 1920 was participated in by those present at the meeting.

Adjourned.

Spokane Association, Organized 1914.

Alfred D. Butler, President; Charles E. Davis, Secretary-Treasurer, 401 City Hall, Spokane, Wash.

The regular meetings of the Association are held on the second Friday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Visiting members are invited to attend the meetings.

Texas Association, Organized 1913.

Hans Helland, President; E. N. Noyes, Secretary, Dure Building, Dallas, Tex.

(Abstract of Minutes of Meetings)

October 17th, 1919.—The Semi-Annual Meeting of the Association was called to order in the Chamber of Commerce Building, Fort Worth, Tex., at 10.30 A. M.; President Potts in the chair; J. H. Brillhart, Secretary; and present, also, 19 members.

Dr. C. C. Gumm, Manager of the Fort Worth Chamber of Commerce, delivered the address of welcome, to which President Potts responded.

The minutes of the previous meeting were read and approved.

The following Committee on Resolutions was appointed: Messrs. E. N. Noyes, Chairman, J. C. McVea, and F. J. Von Zuben.

On motion, duly seconded, the stand of *Engineering-News Record* in not yielding to the demands of the printers during the recent strike in New York City, was endorsed, and the President sent a telegram to the management relative to the Association's endorsement of its action.

The subject of the proposed National Department of Public Works was discussed by Messrs. W. J. Powell, Davis, Windrow, Brillhart, and Potts.

The question of the place for holding the 1920 Annual Convention of the Society was discussed generally.

The meeting reconvened at 3.00 P. M.; President Potts in the chair; J. H. Brillhart, Secretary.

The meeting was addressed by Mr. C. S. Fowler, of the State Highway Commission, on "Seventy-five Million Dollar Bond Issue Amendment" and also on the Maintenance Tax Amendment, and the subject was discussed by Messrs. Dutton, McClellan, Windrow, and Potts.

Mr. Brillhart presented the report of the Committee on Development, and Mr. Howe presented the report of the Highway Committee. On motion, duly seconded, the Highway Committee was continued.

Mr. J. M. Howe, Chairman, presented the report of the Licensing Committee and, on motion, duly seconded, the Committee was discharged with thanks.

Adjourned.

The meeting reconvened at 9.00 P. M.; President Potts in the chair; J. H. Brillhart, Secretary.

The following officers for 1920 were elected: President, Hans Helland; First Vice-President, C. M. Davis; Second Vice-President, J. H. Brillhart; and Secretary-Treasurer, E. N. Noyes.

A paper by Mr. J. C. Nagle, entitled "Administration Problems of Maintenance of Efficiency in Engineering Instruction" was presented by the author, which was followed by a brief address by Professor Giesecke on "Rodding Concrete".

Twelve engineers were elected to membership in the Association.

Adjourned.

October 18th, 1919.—The meeting was called to order at 10.30 A. M. at the Chamber of Commerce Building; President Potts in the chair; J. H. Brillhart, Secretary

On motion, duly seconded, a Publication Committee was appointed.

The report of the Treasurer was presented and, on motion, duly seconded, was accepted.

On motion, duly seconded, the Secretary was instructed to write to the Board of Directors endorsing the action of the Pittsburgh Association in reference to the compensation of engineers.

On motion, duly seconded, the Board of Directors and Mr. Howe were instructed to canvass the city and decide where the 1920 Annual Convention of the Society should be held. Later, the Committee decided that the Society be invited to hold its Annual Convention in Houston, with visits to Galveston and San Antonio, which decision was, on motion, duly seconded, approved as the unanimous vote of the Texas members.

The meeting was addressed by Mr. Harry Hawgood, Director from the 11th District, on the subjects of 1920 Annual Convention and the Report of the Committee on Development of the Society.

Adjourned.

Utah Association, Organized 1916.

A. B. Villadsen, President, 304 Dooly Bldg., Salt Lake City, Utah.

The Annual Meeting of the Association is held on the first Wednesday in April. The time of other meetings is not fixed, but this information will be furnished on application to the President.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcome in the Reading Rooms and at the meetings of many engineering societies in all parts of the world. A list of such societies will be found on pages 41 and 42 of the Year Book of the Society for 1919.

ANNUAL REPORT OF THE BOARD OF DIRECTION FOR THE YEAR ENDING DECEMBER 31st, 1919.

In compliance with the Constitution, the Board of Direction presents its report for the year ending December 31st, 1919:

MEMBERSHIP

The changes in membership are shown in the following table:

	Jan. 1st, 1919.			Jan. 1st, 1920.			Losses.				Additions.		Totals.		
	Resident.	Non-Resident.	Total.	Resident.	Non-Resident.	Total.	Transfer.	Resignation.	Dropped.	Death.	Transfer.	Election.	Loss.	Gain.	Increase.
Honorary Members	.....	3	3	.....	3	3	....	..	..	...	.....	.....	....	....	...
Corresponding "	.....	1	1	.....	1	1	....	..	..	...	.....	.....	....	....	...
Members	688	3 094	3 782	762	3 232	3 994	....	16	..	61	*162	‡127	77	289	212
Associate Members	612	3 768	4 380	694	4 015	4 709	162	46	1	21	†101	‖458	230	559	329
Associates	61	104	165	65	104	169	1	3	..	1	.....	9	5	9	4
Juniors	110	482	592	116	406	522	100	21	35	7	.....	¶93	163	93	§70
Fellows	.....	10	10	.....	10	10	....	..	..	..	.....	.....	....	....	...
Totals	1 471	7 462	8 933	1 637	7 771	9 408	263	86	36	90	263	687	475	950	475

* 162 Associate Members.
† 1 Associate, 100 Juniors.
‡ 3 Reinstatements.
‖ 4 Reinstatements.
¶ 1 Reinstatement.
§ Decrease.

The net increase in membership for the year is 475.

The total number of applications received has been 1 196: 873 for admission and 323 for transfer.

The losses by death during the year number 90, and are as follows:

Members (61): Hermon Charles Allen, William Archer, Percy Herbert Ashmead, Owen Brainard, Holland Williams Baker, Frederick Brooks, Ralph Henry Brown, Stephen Pearson Brown, Rolla Clinton Carpenter, Charles Titus Church, Theodore Cooper, Chester Birge Davis, Adna Dobson, William Thomas Dougan, William Griffing Ford, Archibald Smith Frew, Harvey Mosher Geer, Walter Hayden Graves, Harry Hardy, William Appleton Haven, Arthur Haviland, John Vose Hazen, James Nisbet Hazlehurst, John Gibson Hendrie, Albert James Himes, Henry Wilson Hodge, Frank Churchill Horn, Rufus Cameron Hunt, Linn Murdoch Huntington, Charles Mattathias Jacobs, Thomas William Jaycox, Tien Yow Jeme, Norman Benjamin Kellogg, Paul Sourin King, Marvin Watson Kingsley, George Stevens Leavenworth, Henry Manley, Robert Edgar Milligan, George Clark Mills, William

Newbrough, Lewis Abel Nichols, John Patrick O'Donnell, John Christian Ostrup, Henry Kinder Owens, Carl Redlich, Homer Peter Ritter, Henry Burger Sauerman, Hermann Frederick August Schussler, Naoji Shiraishi, Hiram Joseph Slifer, Raphael Chart Smead, Fred Caswell Stanton, Frederic Pike Stearns, Henry Morton Stone, Mason Romeyn Strong, Emil Swensson, George Sykes, Carl Uhlig, Robert Van Buren, Rufus Mason Whittet, Irving Sparrow Wood.

Associate Members (21): Paul Jones Bean, Bernt Berger, Charles Edwin Bright, Gustavo Adolfo Dubois, William Wetmore Gibbs, Norman Marshall Halcombe, Robert Dwiggins Monteith Henley, John William Horton, Grandville Reynard Jones, Paul Robert Kirstein, Charles H. Knowles, Angus Robert Mackay, Thomas Hatcher Matson, Allen Eugene Nichols, Walter Scott Obermeyer, George Thomas Petheram, Alexander Charles Schilling, George Hippesley Stanley Stephens, George M. Stevens, Burt Stimson, Rafael Joaquin Torralbas.

Associates (1): Hugh Monroe Wilson.

Juniors (7): Victor Hugo Bell, Dean Chase, Ralph Richardson Marrian, Charles Gilbert Reilly, Hugo S. Speidel, Jay William Toms, John Wesley White.

LIBRARY

The combined Engineering Societies Library (to which, it will be remembered, the 67 000 volumes of this Society have been transferred but which still belong to this Society) received during 1919 a total of 2 937 volumes (2 384 by gift, 553 by purchase), 3 437 pamphlets (3 205 by gift, 232 by purchase), and 118 maps and plans, making a total of 148 870 now in the permanent collection. The American Institute of Mining and Metallurgical Engineers transferred to the Engineering Societies Library the income from a bequest of $100 000 by Dr. James Douglas, amounting to approximately $5 000.

The expenditures for the work of the Library amounted to about $24 000. A continually increasing use of the Library is indicated in the total attendance for the year, which reached 22 042 as compared with 12 820 in 1915; 13 848 in 1916; 11 381 in 1917; and 15 063 in 1918. The attendance after 6 P. M. was 15%, or 3 470. The average daily attendance was 72.

The work of reclassifying and recataloguing, for which each of the four Founder Societies is contributing $2 500 per year for two years, was begun July 1st, and 6 671 volumes have been catalogued at an expense of about $4 360.

The Service Bureau approximately paid for itself, with a total income of about $19 000. It made during the year 552 searches and copies of searches, and 71 translations, totaling 227 300 words. The value of the equipment for making photographic copies of articles has been more evident than ever before and the demands at times have

taxed the capacity of the Bureau to the limit. The orders amounted to 2 319 and required 23 951 prints, an increase of 101% over the number of orders in 1918.

READING ROOM

The Reading Room of the Society has shown an increase in the attendance, as compared with that of 1918, of about 31%, the total for the year being 4 283. The facilities for correspondence, for receiving mail, and for obtaining general information have been increasingly used. During the past year there have been received regularly 290 technical and non-technical magazines. Several new periodicals have been added to the list, while others received heretofore have been suspended from publication owing to war conditions. The more important technical periodicals are indexed and kept on file for ready reference. The collection of recent technical books has been enlarged, both by purchase and by donation from members of the Society.

The Reading Room attendants prepared the list of references to current engineering literature for *Proceedings,* which required 93 pages and contained 3 725 classified references to 89 periodicals. Some of the French and German periodicals which were not available during the War are now regularly received and indexed.

COMMITTEES

There are at present four Special Committees appointed to report on Engineering subjects, namely: To Codify Present Practice on the Bearing Value of Soils for Foundations; Regulation of Water Rights; Stresses in Railroad Track; and Highway Engineering. A second Progress Report has been received from the Committee on Stresses in Railroad Track, and Progress Reports are expected from two of the other Committees.

The Final Report of the Committee on Engineering Education was presented at the last Annual Meeting and the Committee was discharged.

The Special Committee on Highway Engineering was appointed by the Board during the year, to keep in touch with the development of the Government's plan for the construction and financing of National highways and to advise the Society of these plans and activities by the submission of frequent or periodic reports or critical reviews.

The Final Report of the Committee on Development has been forwarded to all members of the Society, and will be one of the topics for discussion at the Annual Meeting.

DELEGATION TO VISIT FRANCE

The object of this Delegation was to discuss with the French engineers the large engineering problems now facing France. The result of their visit and deliberations was published in *Proceedings* for August, 1919, pages 604-680.

A Permanent Franco-American Engineering Committee has been formed of two members appointed by each of the four Founder Societies.

ENGINEERING SOCIETIES EMPLOYMENT BUREAU

As announced in the last Annual Report, the Engineering Societies Employment Bureau was established under the management of the Secretaries of the four Founder Societies.

During the year more than 20 000 men have been interviewed, and 5 377 have registered with the Bureau. Of these, 1 256 are known to have been placed, but this does not represent the result because of the difficulty of getting reports from men after they have obtained positions. The large number of daily visitors to the Bureau indicates clearly that it was much needed, and that it will be of increasing value as the work it is doing becomes better known to employers.

PUBLICATIONS

During the year eight numbers of *Proceedings,* one volume of *Transactions,* and one Year Book have been issued. Owing to a strike in the printing trade, it was not possible to issue the October and November numbers of *Proceedings;* the number for December covered the last three months of 1919.

As a war measure and a matter of economy, it was decided last year that no volume of *Transactions* should be issued in 1919. It is expected that publication will be resumed next year. At the present time nearly 1 600 pages of type matter are being held for this purpose.

During the year the membership was canvassed to determine whether the Year Book should be changed to contain a single alphabetical list, without separate divisions for the various grades. The vote being favorable, the Year Book for 1920 will be published in the revised form. The Roll of Honor will be printed in this Year Book, to provide a permanent record of those who took part in the World War.

The stock of the various publications of the Society, kept on hand for the convenience of members and others, now amounts to 152 317 copies, the cost of which to the Society, for paper and press work only, has been $22 934.56.

Summary of Publications for 1919

	Issues.	Average edition.	Total pages.	Plates.	Cuts.
Proceedings (monthly numbers)....	8	9 100	2 096	19	144
Transactions, Vol. LXXXII......	1	9 000	1 775	48	610
Year Book	1	9 400	415	1	..
Total	10	....	4 286	68	754

The cost of publications has been:

For Paper, Printing, etc., *Proceedings* and *Transactions*	$30 502.18
For Plates and Cuts	1 128.53
For Boxes, Copyright, and Sundry Expenses	451.98
For 5 971 Extra Copies of Papers and Memoirs	338.88
For Year Book	4 408.31
Total	$36 829.88
Deduct amount received from sale of publications	3 234.19
Net expenditure for publications for 1919	$33 595.69

Vol. LXXXII, which was published during this year, was really the volume of *Transactions* for the year 1918.

MEETINGS

Twenty-three meetings were held during the year, as follows: At the Annual Meeting, 3; at the Annual Convention 3; and 17 other meetings, all of which were held at Society Headquarters in the Engineering Societies Building.

At these meetings there were presented 5 formal papers, 3 of which were illustrated with lantern slides, 8 lectures and addresses, 6 of which were illustrated with lantern slides and motion pictures, and 8 informal discussions, 3 of which were illustrated with lantern slides. The number of members and others who took part in the preparation and discussion of these papers, lectures and addresses, and informal discussions was 155.

The Annual Convention, which had been abandoned for two years on account of war conditions, was held in the "Twin Cities" of St. Paul and Minneapolis, Minn., from June 17th to 20th, 1919, inclusive.

The total attendance at the 23 meetings was about 4 151. The registered attendance at the Annual Meeting was 933, and at the Annual Convention 149, but this does not include many members and guests present, who failed to register.

In the absence of regularly scheduled technical papers, the following topics have been presented, many of which have been illustrated by lantern slides:

January 15, 1919, "The Construction Work Carried on in the United States During the War", by Brig.-Gen. R. C. Marshall, Jr., U. S. A.

January 16, 1919, "The War and the American Soldier", by Brig.-Gen. S. T. Ansell, U. S. A.

February 19, 1919, "New Developments in Concrete", by Nathan C. Johnson.

March 5, 1919, "Engineering Construction in Russia, and General Conditions in that Country from the Viewpoint of an Engineer", by Vladimir V. Goriachkovsky.

March 19, 1919, "The New York and New Jersey Vehicular Tunnel": An Informal Discussion.

April 16, 1919, "American Highways": An Informal Discussion.

May 21, 1919, "Fixed Ammunition Loading, Inspecting, and Firing", by Joseph Dean Evans.

June 4, 1919, "The Organization of a Local Association of Members of the Society in the New York City District": An Informal Discussion.

June 17, 1919, "Engineering Activities of the 'Twin Cities' ", by F. C. Shenehon.

June 19, 1919, "The Work of Army Troops of the American First Army in France", by F. W. Scheidenhelm.

September 17, 1919, "The Need of a National Department of Public Works": An Informal Discussion.

October 15, 1919, "The Relation of the Engineer to the Future Military Activities of the United States": An Informal Discussion.

November 5, 1919, "The Compensation of Engineers": An Informal Discussion.

November 19, 1919, "The Proposed Nationalization of Railroads in the United States": An Informal Discussion.

December 3, 1919, The Report of the Committee on Development of the American Society of Civil Engineers: An Informal Discussion.

December 17, 1919, "An Engineer's Rambles in Central and South America", by William V. Alford.

The Board Room, Past-Presidents' Room, and General Office of the Society, in addition to their use by the Board of Direction and by Committees of the Society, have been used by other organizations (United Engineering Society, Americanization Committee, National Research Council, American Welding Society, American Society of Mechanical Engineers' Committees, Engineering Foundation, Engineering Council, American Society for Testing Materials, War Department Sub-Committees, and sixteen others) for 88 meetings.

MEDALS AND PRIZES

For the year ending with July, 1918, prizes were awarded as follows:

The Norman Medal to L. R. Jorgensen, M. Am. Soc. C. E., for his paper entitled "Multiple-Arch Dams on Rush Creek, California".

The J. James R. Croes Medal to Israel V. Werbin, Assoc. M. Am. Soc. C. E., for his paper entitled "Tunnel Work on Sections 8, 9, 10, and 11, Broadway-Lexington Avenue Subway, New York City".

The Thomas Fitch Rowland Prize to F. W. Scheidenhelm, M. Am. Soc. C. E., for his paper entitled "The Reconstruction of the Stony River Dam".

The James Laurie Prize to Charles W. Staniford, M. Am. Soc. C. E., for his paper entitled "Unusual Coffer-Dam for a 1 000-Foot Pier, New York City".

The Collingwood Prize for Juniors to James B. Hays, Jun. Am. Soc. C. E.*, for his paper entitled "Designing an Earth Dam Having a Gravel Foundation, with the Results Obtained in Tests on a Model".

MEMBERS IN SERVICE

There were 1 823 members of the Society in the Military or Naval Service of the United States or its Allies, according to the records of the Secretary's office. Of these there were in the American Army 1 610, American Navy 113, British Army 65, French Army 8, and Italian Army 1.

A general summary of this service follows:

Armies		American Navy	
Major-Generals	10	Rear-Admirals	5
Brigadier-Generals	21	Captains	7
Colonels	80	Commanders	20
Lt.-Colonels	87	Lt.-Commanders	16
Majors	334	Civil Engineers (rank not given)	6
Commandant	1	Lieutenants	28
Captains	669	Lieutenants (Junior Grade)	17
First Lieutenants	312	Ensigns	10
Second Lieutenants	95	Chief Machinist's Mate	1
Master Engineers	8	Chief Carpenter's Mate	1
Master Gunners	2	Marine	1
Sergeants	31	Miscellaneous	1
Corporals	10	Total	113
Privates	23		
Students, Training Camps	18		
Miscellaneous	9		
Total	1 710		

Total, 1 823.
Died in Service, 26.

FINANCES.

Inasmuch as in the last Annual Report the general financial condition of the Society was discussed fully, it appears to be unnecessary

* Now Assoc. M. Am. Soc. C. E.

to repeat details. This year has not been quite so difficult financially. The deficit of \$20 000 on last year's business has been paid in full, and while a temporary loan had to be negotiated last Autumn in order to pay current bills, the amount was less than was necessary for a similar purpose in 1918.

Arrangements have been made, and will go into effect on February 1st, 1920, for a reduction in the rate of interest on the \$200 000-mortgage debt on the Fifty-seventh Street property from 6% to 5%.

The Reports of the Secretary and of the Treasurer are appended.

By order of the Board of Direction,

CHAS. WARREN HUNT,
Secretary.

GENERAL BALANCE SHEET, DECEMBER 31st, 1919.

Accompanying Report of the Secretary.

Assets.

Three Lots (actual cost $185 406.20) Estimated Value		$350 000.00
Building		194 523.52
New Society Headquarters		5 100.00
Furniture		59 660.08
Publications on hand (inventoried cost)		22 934.56
New York City, non-taxable 4¼% Bonds		10 300.00
Interest accrued on Investment		141.67
Library:		
Cash expended for books, etc.	$22 122.22	
Donations (estimated)	72 310.83	94 433.05
Equity in U. E. S. Building		486 792.79
Alfred Noble Memorial (Loan)		1 200.00
Due from Members		26 445.35
Due from Non-Members		1 230.63
Cash		27 920.65
		$1 280 682.30

Liabilities.

Dues for 1920 paid in advance		$37 704.43
Mortgage		200 000.00
Interest accrued on Mortgage		5 000.00
Funds invested in Society House, Lots and Library*		29 840.78
Herbert Steward Library Fund		2 060.00
Joseph G. Swift Library Fund		1 030.00
Balance of Donation on account of work of Special Committee		2 188.03
Surplus	$995 649.06	
Reserve Fund	7 210.00	1 002 859.06
		$1 280 682.30

*Compounding Dues Fund, $13 580.00; Norman Medal Fund, $1 000.00; Rowland Prize Fund, $1 222.50; Collingwood Prize Fund, $1 000.00; Fellowship Fund, $13 038.28.

REPORT OF THE SECRETARY FOR THE

To the Board of Direction of the

Gentlemen:—I have the honor to present a statement of Receipts and Disbursements for the fiscal year of this Society, ending December 31st, 1919. I also append a general Balance Sheet showing the affairs of the Society.

Respectfully submitted,
Chas. Warren Hunt,
Secretary.

Receipts.

Balance on Hand, December 31, 1918		$31 846.75
Entrance Fees	$18 455.00	
Current Dues	95 052.18	
Past Dues	6 061.18	
Advance Dues	37 704.43	
Certificates of Membership	872.26	
Badges	4 145.13	
Sales of Publications	3 234.19	
Annual Meeting	2 070.70	
Binding	4 623.11	
Interest	765.55	
Miscellaneous	1 098.89	
Compounding Dues	1 250.00	
Rent, 220 W. 57th St	5 470.24	
Rent, Rooms 1605-1607	590.05	
Delegation to France	98.07	
Loan from C. W. Hunt	5 000.00	
		186 490.98
		$218 337.73

YEAR ENDING DECEMBER 31st, 1919.

American Society of Civil Engineers.

Disbursements.

Salaries of Officers	$15 704.81*	
Clerical Help	27 008.62	
Publications	36 829.88	
Postage	8 998.20	
General Printing	7 439.82	
Office Supplies	2 727.62	
Badges	3 092.33	
Certificates of Membership	575.40	
Binding	5 132.49	
Reading Room Maintenance	317.14	
United Engineering Society:		
General Assessment for Space	8 318.24	
Engineering Council	4 000.00	
Library Board	5 249.98	
Employment Bureau	1 500.00	
Meetings and Miscellaneous	1 476.87	
Furniture	290.35	
Mileage of Directors	7 129.71	
Mileage of Nominating Committee	1 069.40	
Mileage of Special Committees	5 555.72	
Work of Committees	2 377.43	
Prizes	261.95	
Annual Meeting	3 177.71	
Annual Convention	939.17	
Interest on Mortgage	9 730.59	
Insurance	601.20	
Current Business	4 573.89	
Petty Expenses	46.13	
Miscellaneous	446.26	
Refunding Dues	70.40	
Delegation to France	2 128.06	
Alterations to 57th St. Building	18 647.71	
Payment of loan to C. W. Hunt	5 000.00	
		$190 417.08
Balance on hand December 31st, 1919:		
In Garfield National Bank	26 420.65	
In Hands of Secretary	1 500.00	
		27 920.65
		$218 337.73

* Secretary, $12 000; Treasurer, $100; Assistant Secretary, $4 000.

REPORT OF THE TREASURER OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS FOR THE YEAR ENDING DECEMBER 31st, 1919.

In compliance with the provisions of the Constitution I have the honor to present the following report for the year ending December 31st, 1919:

Balance on Hand, December 31st, 1918			$31 846.75
Receipt from current sources, January 1st to December 31st, 1919		$181 490.98	
Temporary loan from C. W. Hunt		5 000.00	
			186 490.98
Payment of audited vouchers for current business, January 1st to December 31st, 1919		$154 542.52	
Engineering Council		4 000.00	
Library Board		5 249.98	
Employment Bureau		1 500.00	
Meetings and Miscellaneous		1 476.87	
Final Payments on account of Alterations to 57th Street Building		18 647.71	
Refund to C. W. Hunt of temporary loan		5 000.00	
Balance on Hand December 31st, 1919:			
In Garfield National Bank	$26 420.65		
In Hands of Secretary	1 500.00	27 920.65	
		$218 337.73	$218 337.73

Respectfully submitted,

ARTHUR S. TUTTLE,
Treasurer.

NEW BOOKS*

(From December 1st to December 31st, 1919)

The statements made in these notices are taken from the books themselves, and this Society is not responsible for them.

DONATIONS TO ENGINEERING SOCIETIES LIBRARY

ELECTRICAL ENGINEERING PAPERS:

A Collection of the Author's most Important Engineering Papers Presented before Various Technical Societies and Published in Engineering Journals and Elsewhere from Time to Time. By Benjamin G. Lamme. Westinghouse Electric & Mfg. Co., 1919. 773 pp., illus., 9 x 6 in., cloth. $2.50. (Gift of Author.)

A collection of thirty-one papers and addresses which have appeared in various periodicals during the period from 1897 to 1918. These papers deal with problems of generator and motor design, the history of direct-current generators and of street railway motors, and with technical training. The volume is published by the Westinghouse Electric and Manufacturing Company to commemorate Mr. Lamme's connection with it for thirty years.

SELENIUM CELLS:

The Construction, Care and Use of Selenium Cells with Special Reference to the Fritts Cell. By Thomas W. Benson. N. Y., Spon and Chamberlain; Lond., E. & F. N. Spon, Ltd., 1919. 63 pp., 18 illus., 8 x 5 in., cloth. $1.50.

The lack of definite information on the construction of selenium cells has led the author to publish the results of some of his experiments. After a brief review of various types of cells, the book describes in detail the manufacture, maturing, and testing of the Fritts cell, and concludes with an account of some applications and suggestions on the care of cells.

GUIDE TO THE STUDY OF THE IONIC VALVE:

Showing Its Development and Application to Wireless Telegraphy and Telephony. By William D. Owen. Lond., Sir Isaac Pitman and Sons. 59 pp., 12 illus., 6 x 4 in., cloth. $1.00.

This little volume is intended to provide, for students of radio-telegraphy, an impartial, coherent record of the development of the ionic valve. References to the original sources of the information enable the reader to pursue his study of the subject.

OIL ENGINES: DETAILS AND OPERATION.

By Lacey H. Morrison. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1919. 472 pp., illus., tab., diagrams, 9 x 6 in., cloth. $5.00.

This volume is intended for operators of oil engines. The details of construction of the more important oil engines manufactured in the United States are described and the proper methods of adjustment are explained at length.

MACHINE TOOL OPERATION:

Part I, The Lathe Bench Work and Work at the Forge. By Henry D. Burghardt. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1919. 326 pp., illus., tab., 8 x 5 in., cloth. $2.00.

The author of this work has used his experience as a teacher of machine work in a technical high school to prepare a textbook for those who desire a knowledge of the principles and elementary operations of machine shop work, suitable for use in technical and trade schools and in apprenticeship courses. While designed primarily for use in connection with lectures by an instructor, it is also useful for self-instruction.

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* Unless otherwise specified, books in this list have been donated by the publishers.

ELEMENTARY PRINCIPLES OF AEROPLANE DESIGN AND CONSTRUCTION:

A Textbook for Students, Draughtsmen, and Engineers. By Arthur W. Judge. Lond. and N. Y., James Selwyn and Co., Ltd., 1919. 116 pp., 56 illus., 13 tab., 9 x 6 in., cloth. $3.00. (Gift of Isaac Pitman & Sons.)

Written to provide an inexpensive book, of an elementary nature, dealing with the fundamental principles of the design and, to a certain extent, the construction of airplanes. It follows the plan of the author's larger work, to which it may serve as an introduction.

CLAY PLANT CONSTRUCTION AND OPERATION.

By A. F. Greaves-Walker. Chicago, Brick and Clay Record, 1919. 212 pp., 79 illus., 9 x 6 in., cloth. $4.00.

In writing this work the author has attempted to explain in understandable English some of the problems of the manufacturer of structural clay products. Technical terms, formulas, and theories have been avoided, and practical facts alone are presented.

METAL WORKER'S HANDY-BOOK OF RECEIPTS AND PROCESSES:

Being a Collection of Chemical Formulas and Practical Manipulations for the Working of All the Metals and Alloys; Including the Decoration and Beautifying of Articles Manufactured Therefrom, as Well as Their Preservation. Edited by William T. Brannt. New enlarged edition. N. Y., Henry Carey Baird and Co., Inc., 1919. 582 pp., illus., tab., 8 x 5 in., cloth. $3.00.

Five new chapters have been added to the present edition of this work, describing methods for welding with the oxy-acetylene flames, thermit, and electricity, for galvanizing and for die-casting.

THE MANUFACTURE AND TESTING OF MILITARY EXPLOSIVES.

By John Albert Marshall. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1919. 261 pp., 8 x 6 in., cloth. $3.00.

This volume contains a concise account of the explosives used for military purposes, in which attention is directed to those points which have a direct bearing on the manufacture, testing, and storage of these substances. An extensive bibliography is included.

THE PETROLEUM HANDBOOK.

By Stephen O. Andros. Chic., The Shaw Publishing Co., 1919. 206 pp., illus., tab., 7 x 4 in., flexible cloth. $2.00.

In a book of pocket size, the author gives the fundamentals of each phase of the oil industry necessary to a clear understanding of the various operations entailed between the location of an oil well and the distribution of the refined products. The work is chiefly a compilation from the standard authorities, arranged for those who wish a brief, accurate account of the industry, devoid of unnecessary detail.

PRINCIPLES OF INDUSTRIAL ORGANIZATION.

By Dexter S. Kimball. 2d edition, revised and enlarged. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1919. 325 pp., 21 illus., 1 pl., 12 tab., 9 x 6 in., cloth. $3.00.

This work, the first edition of which appeared in 1913, has been written to give young engineers a concise account of the salient facts regarding the most important economic and sociological problems with which they will be brought in contact, and to explain the origin and growth of the important features of industrial organization. The present edition has been revised, re-arranged, and enlarged.

WHEN THE WORKMEN HELP YOU MANAGE.

By William R. Basset. N. Y., The Century Co., 1919. 266 pp., 7 x 5 in., cloth. $2.00.

The author states that, as a result of large practical experience, he has come to the conclusion that right relations between employers and employees depend on the establishment of arrangements by which both parties may express themselves in their work, without the intervention of outside agencies. In this book he develops certain principles underlying satisfactory relations and gives examples of their successful application by various industrial concerns.

MILLIONS FROM WASTE.

By Frederick A. Talbot. Phila., J. B. Lippincott Co.; Lond., T. Fisher Unwin, Ltd., 1920. 308 pp., 9 x 6 in., cloth. $5.00.

This work is written to indicate certain of the most obvious channels through which wealth incalculable is being permitted to escape, as well to describe some of the highly ingenious efforts which are being made to prevent this wastage. While written essentially for the uninitiated, it will, the author hopes, prove of aid to those who are fully alive to the potential values of refuse. The volume is confined to those phases of the subject which are familiar to the average person.

INDUSTRIAL RECONSTRUCTION PROBLEMS:

Complete Report of the Proceedings of the National Engineers, New York City, March 18th-21st, 1919. 197 pp., 9 x 6 in., paper.

The papers presented at the conference dealt with a wide variety of problems connected with the reorganization of our industries on a peace basis. Consideration is given to questions of finance, commerce, production, labor, education, management, etc.

TECHNO-CHEMICAL RECEIPT BOOK:

Containing Several Thousand Receipts and Processes, Covering the Latest, Most Important and Most Useful Discoveries in Chemical Technology and Their Practical Application in the Arts and the Industries. Compiled and Edited by William T. Brannt and William H. Wahl. New enlarged edition. N. Y., Henry Carey Baird and Co., Inc., 1919. 516 pp., illus., tab., 8 x 5 in. $2.50.

The principal aim in preparing this work has been to give a compendious collection of approved receipts and processes of practical applications in the industries. The receipts have been principally derived from German sources and most of them have been tested practically. The present edition has been revised and various receipts added.

TECHNISCHER LITERATURKALENDER, 1918.

München-Berlin, R. Oldenbourg. 640 columns, 1 por., 8 x 6 in., cloth. 12 marks plus 20% increase.

This volume is a concise biographical dictionary of living German authors of technical and scientific books, compiled by the Librarian of the German Patent Office. Over five thousand writers are included. The information given includes their addresses, education, age, occupations, technical specialties, publications, etc.

APPLIED SCIENCE FOR METAL WORKERS;

Applied Science for Wood-Workers. By William H. Dooley. N. Y., The Ronald Press Co., 1919. $2 each.

These volumes present a course in the general principles of science, which gives particular attention to their applications in industry and is intended for use in vocational high schools, industrial schools, apprentice classes, etc. The general scientific matter in the two books is identical. Additional material relating specifically to the wood-working trades appears in one, while the other treats of metal-working in similar fashion.

BUILDING OF THE PACIFIC RAILWAY:

The Construction Story of America's First Iron Thoroughfare between the Missouri River and California, from the Inception of the Great Idea to the Day, May 10, 1869, when the Union Pacific and the Central Pacific joined Tracks at Promontory Point, Utah, to Form the Nation's Transcontinental. By Edwin L. Sabin. Philadelphia and London, J. B. Lippincott Co., 1919. 317 pp., 10 pl., 4 por., 1 map, 8 x 5 in., cloth. $2.00.

Mr. Sabin's object has been to tell how the Pacific Railway came into being; to describe the actual building operations by which the Union Pacific Railroad, from the Missouri River, and the Central Pacific Railroad, from the Sacramento River, were constructed in six years instead of the allotted fourteen. The book is a popular, readable account of the men who built the roads and of the methods used.

STRENGTH OF MATERIALS:

A Textbook for Technical and Industrial Schools. By John Paul Kottcamp. N. Y., John Wiley and Sons, Inc.; Lond., Chapman and Hall, Ltd., 1919. 193 pp., illus., 19 tab., 8 x 5 in., cloth. $1.50.

The course of instruction presented in this textbook sets forth the fundamental principles with a minimum of mathematics, and shows the application of these principles by a large number of examples which are worked out in detail. The book is based on the author's course in the subject at Pratt Institute.

MEMBERSHIP

(From December 4th, 1919, to January 8th, 1920)

ADDITIONS

MEMBERS

Members	Grade	Date of Membership.
ACHER, ALBERT HILANDS. Chf. Engr., U. S. Food Products Corporation, Hotel Jefferson, Peoria, Ill. (Res., 1720 Twenty-first St., N. W., Washington, D. C.)	Assoc. M. M.	April 7, 1915 Nov. 25, 1919
BERENTS, HANS. Cons. Engr., 15 Nanking Rd., Shanghai, China	Assoc. M. M.	Mar. 13, 1917 Oct. 15, 1919
BUSHNELL, HORACE LELAND. Engr. and Estimator, Grant Smith & Co., 944 Henry Bldg., Seattle, Wash.		Nov. 25, 1919
BUTLER, ALFRED DICKEY. City Engr., Spokane, Wash.	Assoc. M. M.	Oct. 5, 1909 Nov. 25, 1919
CLAPPER, LELAND. Engr., Bridges and Bldgs., Duluth & Iron Range R. R., Two Harbors, Minn.	Assoc. M. M.	Aug. 31, 1915 Nov. 25, 1919
DITTOE, WILLIAM HENRY. Chf. Engr., Ohio State Dept. of Health, 8 East Chestnut St., Columbus, Ohio	Jun. Assoc. M. M.	May 3, 1910 Oct. 1, 1912 Sept. 9, 1919
FEREBEE, JAMES LUMSDEN. Prin. Asst. Engr., Milwaukee Sewerage Comm., City Hall, Milwaukee, Wis.	Assoc. M. M.	Mar. 2, 1915 Nov. 25, 1919
FOX, HERMAN HENRY. (Fox-Redpath Constr. Co.), 1012 New York Life Bldg., Kansas City, Mo.	Assoc. M. M.	Sept. 5, 1911 Nov. 25, 1919
GREEN, FREDERICK WILLIAM. Vice-Pres., St. L., S. W. Ry. Lines, 6203 Washington Ave., St. Louis, Mo.	Assoc. Assoc. M. M.	May 1, 1907 June 24, 1914 Nov. 25, 1919
HICKS, JOHN ROBERT. Engr. Dept., U. S. Coal & Coke Co., Box 161, Gary, W. Va.		Nov. 25, 1919
HODGMAN, BURT BRADLEY. Chf. Engr., National Water Main Cleaning Co., 50 Church St., New York City		Nov. 25, 1919
HOLLAND, LEON LYNWOOD. R. F. D. No. 1, Saunderstown, R. I.		Nov. 25, 1919
KNOPH, OLAF INGVALD. Cons. Engr. Münch's Gate 7, Christiania, Norway		Oct. 14, 1919
KURTZ, FORD. Res. Engr., J. G. White Eng. Corporation, 43 Exchange Pl., New York City		Nov. 25, 1919
LEE, ARTHUR CARL. Res. Engr., Southern Power Co., Charlotte, N. C.	Assoc. M. M.	Nov. 28, 1916 Nov. 25, 1919
LUKESH, GUSTAVE RUDOLF. Dist. Engr., U. S. Engr. Office, Customhouse, Charleston, S. C.		Nov. 25, 1919
LUSK, CHARLES WINSLOW. Civ. and San. Engr., Pittsburgh Filter & Eng. Co., 165 Mayer St., Oil City, Pa.	Assoc. M. M.	Oct. 1, 1913 Nov. 25, 1919

MEMBERS (*Continued*)

		Date of Membership.
MAGOR, HENRY BASIL. 115 Broadway, New York City	Jun. Assoc. M. M.	April 30, 1895 Mar. 7, 1900 Nov. 25, 1919
MERRIAM, CHARLES ALLEN. Archt. and Engr. (Doyle & Merriam), 20 Seattle National Bank Bldg., Seattle, Wash.	Assoc. M. M.	June 11, 1917 Nov. 25, 1919
RATHJENS, GEORGE WILLIAM. 486 Portland Ave., St. Paul, Minn.	Assoc. M. M.	June 4, 1913 Nov. 25, 1919
SANO, TOJIRO. Engr. in Chf., City of Kobe, City Office, Kobe, Japan		Oct. 14, 1919
SAWYER, DONALD HUBBARD. Mgr., James Stewart & Co., Inc., Statler Hotel, Detroit, Mich.	Assoc. M. M.	April 6, 1909 Nov. 25, 1919
SCHULZ, EDWARD HUGH. Lt.-Col., Engrs., U. S. A., 406 Federal Bldg., Milwaukee, Wis.		Oct. 14, 1919
SCHWENDENER, KARL DEWITT. Structural Engr., 1316 Washington Bldg., Los Angeles, Cal.	Assoc. M. M.	April 1, 1914 Nov. 25, 1919
STIVERS, ARTHUR DUCAT. Asphalt Sales Dept., The Texas Co., 801 Fifth Ave., Fort Worth, Tex.	Assoc. M. M.	Sept. 12, 1916 Nov. 25, 1919
VAN RENSSELAER, ALLEN. Advisory Engr. on Water Supply, Mexican Border Project, Constr. Div., U. S. A., Box 83, Camp Travis, San Antonio, Tex.	Assoc. M. M.	June 24, 1914 Nov. 25, 1919
WILLIAMS, JOHN HUW. Personal Asst. to Engr.-in-Chf., and Dist. Engr., Canton-Hankow Ry., Hankow, China		Oct. 14, 1919

ASSOCIATE MEMBERS

ALLIN, RAY LESTER. Civ. and Hydr. Engr., 766 West 13th St., Oakland, Cal.	Jun. Assoc. M.	Sept. 2, 1914 Nov. 25, 1919
ALTHOUSE, IRVIN HENRY. Supt. and Engr., Terra Bella Irrig. Dist.; Cons. Engr., Alpaugh Irrig. Dist., Porterville, Cal.		Nov. 25, 1919
BAILHACHE, JOHN GOODIN. 478 Sutter St., San Francisco, Cal.	Jun. Assoc. M.	Sept. 2, 1914 Oct. 14, 1919
BAKER, WILLIAM DARTIS. Chf. Engr., Truscon Steel Co., 1258 North 57th St., Philadelphia, Pa.		Sept. 9, 1919
BARKER, EDGAR EARL. Care, Citizens Bank, Nevada City, Cal.		Sept. 9, 1919
BAXTER, WARREN GAMMELL. Cons. Engr., 1104 Turks Head Bldg., Providence, R. I.		Nov. 25, 1919
BERNSTEIN, LEO HARRY. Designer, Concrete Steel Co., 364 West 121st St., New York City		Sept. 9, 1919
BUZBY, ARTHUR DUDLEY. Asst. to Designing Engr., Chile Exploration Co., 120 Broadway, New York City		Nov. 25, 1919

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
CARRUTHERS, ROBERT BRUCE. Care, Transcontinental Oil Co., Comanche, Tex.		Nov. 25, 1919
CARSON, HARRY YOUNG. Engr., Am. Cast Iron Pipe Co., Birmingham, Ala.	Jun. Assoc. M.	Mar. 14, 1916 Oct. 14, 1919
COFFMAN, CLYDE DANIEL. 337 Fernwood Drive, Akron, Ohio		Mar. 11, 1919
COMBS, CLAUDE ARTIST. Asst. Engr. on Constr., A., T. & S. F. System, 612 Harrison St., Porterville, Cal.		Nov. 25, 1919
DE JONGH, ARTHUR FRANCIS. Care, Banco de Fomento, Santiago de Cuba, Cuba.	Jun. Assoc. M.	Dec. 3, 1912 Sept. 9, 1919
DOW, EDWIN ARTHUR. Asst. Hydr. Engr., Power Constr. Co., 35 Harvard St., Worcester, Mass.	Jun. Assoc. M.	Oct. 31, 1911 Oct. 14, 1919
ELLIS, RICHARD. Chf. Designer, Lockwood, Greene & Co., 245 State St., Boston (Res., 448 Broadway, Cambridge), Mass.		June 16, 1919
FOGG, RALPH JUSTIN. Head, Civ. Eng. Dept., Lehigh Univ., South Bethlehem, Pa.		Nov. 25, 1919
FONTAINE, JOHN EATON. Chf. of Party and Res. Engr., Morgan Eng. Co., 622 Goodwyn Inst., Memphis, Tenn.		Nov. 25, 1919
GARLAND, ELDON ADDISON. Chf. Engr., Doheny Oil & Ranch Co. (Ranch Div.), 1202 Garden St., Santa Barbara, Cal.		Nov. 25, 1919
GREEN, ROY MELVIN. Prof. of Highway Eng., Agricultural and Mech. Coll. of Texas, College Station, Tex.		Nov. 25, 1919
GREENLEAF, DONALD LEAL. With Coke Dept., Wisconsin Steel Co., South Chicago (Res., 5463 Blackstone Ave., Chicago), Ill.		Nov. 25, 1919
HART, ARTHUR JOHN. Chf. Representative Engr. in Australia, The Indented Bar & Concrete Eng. Co., Ltd., 375 George St., Sydney, New South Wales, Australia.		Oct. 14, 1919
HAY, WILLIAM WREN. New York Mgr., Les Establissements, A. W. Pidwell of Paris, France, 137 Fife St., Forest Hills, N. Y.		Oct. 14, 1919
HAYNES, HARWOOD SYME. 210 McIver St., Greensboro, N. C.		June 16, 1919
HAYS, JAMES BUCHANAN. (Hays, Sloan & Lewis), 306 Boise City National Bank Bldg., Boise, Idaho.	Jun. Assoc. M.	Oct. 1, 1913 Nov. 25, 1919
HEIDEL, CHARLES SUMNER. Hydrographer, Montana State Engr.'s Office, 608 North Davis St., Helena, Mont.	Jun. Assoc. M.	July 2, 1913 Oct. 14, 1919
HERMAN, RALPH EMERSON, JR. Care, C., M. & St. P. R. R., 421 Wells Fargo Bldg., San Francisco, Cal.		April 14, 1919
JONES, ALFRED. Chf. Deputy County Surv., Los Angeles County, 702 Hall of Records, Los Angeles, Cal.		Nov. 25, 1919

ASSOCIATE MEMBERS (*Continued*)

	Date of Membership.
KIEL, FRANK BURDETTE. (Bird & Kiel), 43 Moore & Turner Bldg., Little Rock, Ark.	Nov. 25, 1919
KING, FRANK ELMER. Mgr., New York Office, Pittsburgh Bridge & Iron Works, 2 Rector St., Room 1426, New York City (Res., 20 Hillside Ave., Newark, N. J.)	Nov. 25, 1919
LETTS, JOSEPH CLINTON. Capt., Engrs., U. S. A., U. S. Gen. Hospital No. 41, Fox Hills, N. Y.	Nov. 25, 1919
McCARTHY, JUSTIN CHARLES. 183 West 87th St., New York City	Nov. 25, 1919
MALVIG, AXEL OSVALD. Y. M. C. A., Detroit, Mich.	Nov. 25, 1919
MARTINEZ, ROLANDO ARNOLDO. With Havana Sewer and Paving Dept.; Cons. Engr., Obispo 59, Havana, Cuba	Jun. Dec. 1, 1908 Assoc. M. Nov. 25, 1919
MILLER, WALTER SCOTT. Asst. Engr., Meigs, Simon & Fearing, Pennsylvania Bldg., Philadelphia (Res., Parkland), Pa.	Nov. 25, 1919
MILLER, WILLIAM AITKEN. Lecturer in Civ. Eng., P. N. Russell School of Eng., Univ. of Sydney, Sydney, New South Wales, Australia	Sept. 9, 1919
MYERS, RICHARD AUSTIN. Care, South-Eastern Underwriters Assoc., Atlanta, Ga.	Nov. 25, 1919
NEELY, MARVIN YOUNG. Hydr. Engr., Birkinbine Eng. Offices, 4628 Spruce St., Philadelphia, Pa.	Nov. 25, 1919
NICKEY, EMIT COIN. Highway Engr. and County Surv., Butler County, Court House, Poplar Bluff, Mo.	Nov. 25, 1919
NIXON, HARRY STILLWELL. Asst. Engr., U. P. R. R., Room 1007, Union Pacific Headquarters Bldg., Omaha, Nebr.	Oct. 14, 1919
ORR, NEWELL HAMILTON. Asst. Engr., Erecting Dept., Am. Bridge Co., 1526 Frick Bldg., Pittsburgh, Pa.	Nov. 25, 1919
PHILLIPS, JOHN MARCH. Res. Engr., Clyde Potts, Lathrop Ave., Boonton, N. J.	Nov. 25, 1919
POLANSKY, THEODORE ARTHUR. Field Constr. Engr., Portland Cement Assoc., 408 Union Trust Bldg., Parkersburg, W. Va.	Nov. 25, 1919
RANDALL, ROBERT HENRY. Cons. and Contr. Engr. (R. H. Randall & Co.), 1250 Nicholas Bldg., Toledo, Ohio	Nov. 25, 1919
ROBERTSON, FONZIE EUGENE. Archt. and Structural Engr. (Taylor, Robertson & Griesenbeck), Southwestern Life Bldg., Dallas, Tex.	Jun. June 11, 1917 Assoc. M. Nov. 25, 1919
ROSENWALD, JESSE. With Maurice C. Couchot, 1560 Sacramento St., San Francisco, Cal.	Nov. 25, 1919
ROSS, WILLIAM CLAIBORNE. Hazen, Ark.	Nov. 25, 1919

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
SCHNABEL, WILLIAM CHARLES. Cons. Engr., 3016 Hartford Rd., Baltimore, Md.		Nov. 25, 1919
SCHUYLER, WALTER WESLEY. Supt. of Agriculture, United Fruit Co., Preston Div., Guaro, Oriente, Cuba.	Jun. Assoc. M.	May 6, 1914 Nov. 25, 1919
SHLESSINGER, JACOB. Junior Engr., U. S. Engr. Office, 2798 West North Ave., Baltimore, Md.		Nov. 25, 1919
SIEMS, VALENTINE BERNARD. Prin. Asst. Engr., Baltimore City Water Dept., Eng. and Constr. Div. (Res., 710 East 33d St.), Baltimore, Md.		Nov. 25, 1919
SINGH, KIRPAL. Sub-divisional Officer, Canal Dept., Irrig. Branch, Punjab Upper Chanab Canal, Jethuwal, Amritsar, India.		June 16, 1919
SPEAR, WILLIAM HOWARD. Res. Engr., W. M. Ledbetter & Co., 601 Pacific Elec. Bldg., Los Angeles, Cal.		Nov. 25, 1919
STANTON, WILLIAM MACY. Senior Progress Engr., Office of the Vice-Pres., U. S. Shipping Board, Emergency Fleet Corporation, Philadelphia (Res., 85 North Lansdowne Ave., Lansdowne), Pa.		Nov. 25, 1919
STRATTMAN, CHARLES ROBERT. 405 Chickasaw Ave., Bartlesville, Okla.		Nov. 25, 1919
SYLLIAASEN, MELVIN OLIVER. Structural Plan Checker, Seattle Bldg. Dept., 510 County City Bldg. (Res., 907 West Howe St.), Seattle, Wash.	Jun. Assoc. M.	Feb. 4, 1914 Nov. 25, 1919
TSAI, PING YE. Asst. Engr., Chinese Govt. Rys., Care, Chuchow-Chinchow Ry., Peking, China.		Oct. 14, 1919
UNGER, WILLIAM LOUIS. Bridge Designer, N. Y. C. R. R., Office of Engr. of Structures, 540 Lexington Ave., Room 631, New York City (Res., 144 One hundred Forty-fourth St., Jamaica, N. Y.)	Jun. Assoc. M.	Oct. 7, 1914 Nov. 25, 1919
WALKER, EDSON OZRO. Mgr., Chicago Dist., Concrete Eng. Co., 140 South Dearborn St., Chicago, Ill.		Nov. 25, 1919
WARREN, ALBERT KENDALL. Senior Engr. and Deputy County Surv., 702 Hall of Records, Los Angeles, Cal.		Nov. 25, 1919
WHITAKER, RALPH WARREN. City Engr. and Supt. of Streets, City Hall, Bakersfield, Cal.		Nov. 25, 1919
WICKHAM, JAMES THOMAS. Lieut., Royal Engrs., Mount Folly, Wexford, Ireland.		Nov. 25, 1919
WILLEY, LEO CECIL. 1455 Leavenworth Ave., Apartment 6, San Francisco, Cal.		Nov. 25, 1919
WILSON, HARRY KEITH. 31 Prospect St., East Orange, N. J.		Nov. 25, 1919
WITT, ROBERT EUBBANK. Prof., Civ. Eng., Univ. of Detroit, 491 Jefferson Ave., East, Detroit, Mich.		Nov. 25, 1919

ASSOCIATE MEMBERS (*Continued*) — Date of Membership.

WOLFE, WALTER McILHANEY. Contr. Engr., North-Eastern Constr. Co., Gen. Delivery, Aberdeen, Md........... Nov. 25, 1919

YOUNG, STELL KAY. Secy. and Asst. Chf. Engr., Miami Conservancy Dist., Care, Conservancy Office, Kenton, Ohio.. Nov. 25, 1919

ASSOCIATES

HUNT, HARRY HAUVER. Gen. Contr. (Grant Smith & Co.), 619 Fernwell Bldg., Spokane, Wash................ Nov. 25, 1919

JUNIORS

CHRISTIAN, VALENTINE. 312 Union Ave., Rutherford, N. J. Nov. 25, 1919

HENRY, JOHN BERNARD. Supt., Imperial Water Co. No. 3, Calipatria, Cal................................ Nov. 25, 1919

JOHNSON, DAVID TERRILL. 2d Lieut., Engrs., U. S. A., The Engr. School, Camp A. A. Humphreys, Va...... Nov. 25, 1919

KINCH, MASON HILL. Office Engr., State of Illinois Dept. of Public Works and Bldgs., Div. of Highways, 302 Apollo Theatre Bldg., Peoria, Ill.............. Nov. 25, 1919

KRAMER, HANS. Capt., Corps of Engrs., U. S. A., The Engr. School, Camp A. A. Humphreys, Va.......... Nov. 25, 1919

McCURDY, BYRON CASPER. Turrel, Ark.................. June 16, 1919

NICHOLS, MARVIN CURTIS. Rockwall, Tex................ Nov. 25, 1919

PACE, RAGSDALE. Gen. Supt. and Designer, B. F. & C. M. Davis, 407 Reynolds Bldg., Fort Worth, Tex........ Nov. 25, 1919

STOCKWELL, HARRY DAVID. Chf. Surv., Operating Dept., Braden Copper Co., Sewell, Rancagua, Chile........ Oct. 14, 1919

RESIGNATIONS

MEMBERS — Date of Resignation.

ASHTON, WILLIAM................................. Dec. 31, 1919

BENEDICT, HERSCHEL ALBERT........................ Dec. 31, 1919

FELLOWS, ABRAHAM LINCOLN......................... Dec. 31, 1919

GARLINGHOUSE, FREDERICK LEMAN.................... Dec. 31, 1919

HUNTER, JOHN BURNAP.............................. Dec. 31, 1919

POLLEYS, WILLIAM VAUGHAN......................... Dec. 31, 1919

RICHARDS, ALBERT LENNOX.......................... Dec. 31, 1919

SHANNAHAN, JOHN NEWTON........................... Dec. 31, 1919

YUILLE, NATHANIEL ALSTON......................... Dec. 31, 1919

ASSOCIATE MEMBERS

ADAMS, EDWARD MAGUIRE............................ Dec. 31, 1919

BANKS, GEORGE HILL............................... Dec. 31, 1919

BECK, ALFRED FORTIN.............................. Dec. 31, 1919

CLOUGH, ALBERT HASKELL........................... Dec. 31, 1919

ASSOCIATE MEMBERS (*Continued*)

	Date of Resignation.
Cook, Richard Bailey	Dec. 31, 1919
Day, Warren Ellis	Dec. 31, 1919
DeLamere, Charles Thomas	Dec. 31, 1919
Edmondson, Ralph Seldon	Dec. 31, 1919
Evans, John Maurice	Dec. 31, 1919
Fain, James Rhea	Dec. 31, 1919
Ferguson, Wilbur Earle	Dec. 31, 1919
Goodman, Leon	Dec. 31, 1919
Green, Arthur Brooks	Dec. 31, 1919
Harrington, Harry Garfield	Dec. 31, 1919
Harris, Frank Sampson Mason	Dec. 31, 1919
Herkness, Lindsay Coates	Dec. 31, 1919
Johnstone, William Bard	Dec. 31, 1919
Keith, Charles Whiteside	Dec. 31, 1919
Kelley, Matthew DeTobin	Dec. 31, 1919
King, Eric Ture	Dec. 31, 1919
Kingsley, Edgar Albert	Dec. 31, 1919
Lee, Charles Henry	Dec. 31, 1919
Leeds, Livingston Allaire	Dec. 31, 1919
Nabstedt, Arthur Theodore	Dec. 31, 1919
Newton, Jewett Beach	Dec. 31, 1919
Patterson, Laurence	Dec. 31, 1919
Rowe, Wilfred Lincoln	Dec. 31, 1919
Stewart, Benjamin Franklin, Jr.	Dec. 31, 1919
Swickard, Andrew	Dec. 31, 1919
Trow, Frank Hamant	Dec. 31, 1919
Wells, Walter Melvin	Dec. 31, 1919
Wiggins, Ralph Raymond	Dec. 31, 1919
Wilson, Harry Percival	Dec. 31, 1919

ASSOCIATES

Irwin, William Clark	Dec. 31, 1919

JUNIORS

Brown, Harry Madara	Dec. 31, 1919
Burr, George Lindsley	Dec. 31, 1919
Darville, Merton Arthur	Dec. 31, 1919
Elliott, Percival	Dec. 31, 1919
Feiner, Mark Antony	Dec. 31, 1919
Gambier-Bousfield, George Edmund	Dec. 31, 1919
Howard, Gerald Branch	Dec. 31, 1919
Morrow, Clarence Edgar	Dec. 31, 1919
Mudd, John Posey	Dec. 31, 1919
Rader, James Wilson	Dec. 31, 1919
Rosenfeld, James Roy	Dec. 31, 1919
Swigart, Clyde Arthur	Dec. 31, 1919

DEATHS

ARCHER, WILLIAM. Elected Member, March 2d, 1881; died November 24th, 1919.

BROWN, STEPHEN PEARSON. Elected Associate Member, October 5th, 1904; Member, November 1st, 1910; died December 6th, 1919.

HIMES, ALBERT JAMES. Elected Associate Member, November 6th, 1895; Member, June 7th, 1899; died November 3d, 1919.

HODGE, HENRY WILSON. Elected Junior, January 5th, 1887; Member, October 2d, 1895; died December 21st, 1919.

HUNTINGTON, LINN MURDOCH. Elected Junior, May 2d, 1905; Associate Member, August 31st, 1909; Member, December 31st, 1913; died November 24th, 1919.

KING, PAUL SOURIN. Elected Member, July 3d, 1889; died October 30th, 1919.

NEWBROUGH, WILLIAM. Elected Member, April 6th, 1904; died November 1st, 1919.

O'DONNELL, JOHN PATRICK. Elected Member, July 5th, 1893; died December 2d, 1919.

SMEAD, RAPHAEL CHART. Elected Member, February 1st, 1905; died November 28th, 1919.

STEARNS, FREDERIC PIKE. (*Past-President.*) Elected Member, October 2d, 1878; died December 1st, 1919.

STRONG, MASON ROMEYN. Elected Member, March 6th, 1901; died December 2d, 1919.

VAN BUREN, ROBERT. Elected Member, June 17th, 1868; died December 16th, 1919.

Total Membership of the Society, January 8th, 1920, 9 417.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(November 22d to December 22d, 1919)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Journal,* Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Journal,* Eng. Inst. of Canada, Montreal, Que., Canada.
(6) *Journal,* Am. Inst. of Archts., Washington, D. C., 50c.
(7) *Gesundheits Ingenieur,* Munich, Germany.
(8) *Stevens Indicator,* Hoboken, N. J., 50c.
(9) *Industrial Management,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News-Record,* New York City, 15c.
(15) *Railway Age,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Electric Railway Journal,* New York City, 10c.
(18) *Railway Review,* Chicago, Ill., 15c.
(19) *Scientific American Supplement,* New York City, 10c.
(20) *Iron Age,* New York City, 20c.
(21) *Railway Engineer,* London, England, 1s. 2d.
(22) *Iron and Coal Trades Review,* London, England, 6d.
(24) *American Gas Engineering Journal,* New York City, 10c.
(25) *Railway Mechanical Engineer,* New York City, 20c.
(26) *Electrical Review,* London, England, 4d.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Royal Soc. of Arts, London, England, 6d.
(32) *Mémoires et Compte Rendu des Travaux,* Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil,* Paris, France, 1 fr.
(36) *Cornell Civil Engineer,* Ithaca, N.Y.
(40) *Zentralblatt der Bauverwaltung,* Berlin, Germany, 60 pfg.
(41) *Elektrotechnische Zeitschrift,* Berlin, Germany.
(42) *Proceedings,* Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées,* Paris, France.
(45) *Coal Age,* New York City, 15c.
(46) *Scientific American,* New York City, 15c.
(47) *Mechanical Engineer,* Manchester, England, 3d.
(48) *Zeitschrift,* Verein Deutscher Ingenieure, Berlin, Germany, 1, 60 m.
(49) *Zeitschrift für Bauwesen,* Berlin, Germany.
(50) *Stahl und Eisen,* Düsseldorf, Germany.
(53) *Zeitschrift,* Oesterreichischer Ingenieur und Architekten-Verein, Vienna, Austria, 70h.
(54) *Transactions,* Am. Soc. C. E., New York City, $16.
(55) *Mechanical Engineering:* Journal, Am. Soc. M. E., New York City, 35c.
(56) *Transactions,* Am. Inst. Min. and Metallurgical Engrs., New York City, $6.
(57) *Colliery Guardian,* London, England, 5d.
(58) *Proceedings,* Engrs.' Soc. of W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings,* American Water Works Assoc., Troy, N. Y.
(60) *Municipal and County Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Drop Forger,* Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 10c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Gas Journal,* London, England, 6d.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(69) *Eisenbau,* Leipzig, Germany.
(71) *Journal,* Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs,* Iron and Steel Inst., London, England.

(72) *American Machinist,* New York City, 15c.
(73) *Electrician,* London, England, 18c.
(75) *Proceedings,* Inst. of Mech. Engrs., London, England.
(77) *Journal,* Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen,* Vienna, Austria, 1, 50m.
(80) *Tonindustrie Zeitung,* Berlin, Germany.
(83) *Gas Age,* New York City, 15c.
(85) *Proceedings,* Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering and Contracting,* Chicago, Ill., 10c.
(87) *Railway Maintenance Engineer,* Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

GROUTING OPERATIONS, CATSKILL WATER SUPPLY

By James F. Sanborn* and M. E. Zipser,* Associate Members, Am. Soc. C. E.

To be Presented February 4th, 1920.

Synopsis

Grout was used extensively in the structures of the Catskill Water Supply System for filling spaces behind the lining of tunnels, for cutting off the flow of water into shafts and tunnels by grouting the water-bearing fissures, for solidifying the foundations and stopping the flow beneath dams, and for various other purposes. The object of this paper is to give a summary of the experience and results obtained in the use of grout in the construction of the aqueduct, dams, and other structures of the Catskill Works, with the hope that it may prove valuable to those undertaking work involving grouting.

Grouting was one of the important operations in the construction of the pressure tunnels of the Catskill Aqueduct. These tunnels, forming about one-third of the total length of the Aqueduct, are subjected to great hydrostatic pressures when in service, and it was essential

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

* New York City.

to make them tight against outward leakage. To prevent the escape of water, grouting was depended on to back up the concrete lining and to close all open seams in the rock adjacent to it. The Aqueduct has been in service for two years, and the slight and practically negligible loss of water from the pressure tunnels is evidence of the complete success of the methods adopted in their construction.

To prevent the percolation of water through porous zones under the Ashokan and Kensico Dams, extensive grouting was done, the grout being forced into the rock seams under air pressure through holes drilled into the ledge rock underneath the dams. To cut off the leakage which had developed underneath the foundations of the two earth dikes at the Ashokan Reservoir, and to improve the foundations, holes were drilled through the core-walls and rolled embankment into the rock and grouted.

Grout was also used to cut off the flow of water during shaft sinking and tunnel driving, in order to permit the work to proceed more rapidly and reduce the expense of pumping. Considerable grouting was also done in connection with repairs in parts of the Rondout, Breakneck, and City Pressure Tunnels, where the lining had been ruptured when the tunnels were subjected to working pressures. The breaks in the lining were due to the yielding of the rock when the test pressures were applied, and grout was injected to fill the cracks in the rock surrounding the tunnel.

Other uses for grout on the Catskill Aqueduct included the lining of large steel pipe lines, the grouting of stretches of poor ground in grade tunnels, the filling of the expansion joint openings in the cut-and-cover aqueduct, and for other purposes. In some of these cases, the grout was not forced in by air pressure, but was placed by pouring or by means of a hand pump.

Grouting in Pressure Tunnels.

The utilization of the pressure-tunnel type is one of the notable features of the Catskill Aqueduct. There are nine pressure tunnels, aggregating 35 miles in length. These tunnels were driven in rock, deep beneath the surface, and were lined with concrete averaging from 18 to 24 in. and more in thickness. They have a finished inside diameter varying from 16 ft. 7 in. to a minimum of 11 ft. The depths of the tunnels below the surface vary from 100 ft. to a maximum of more than

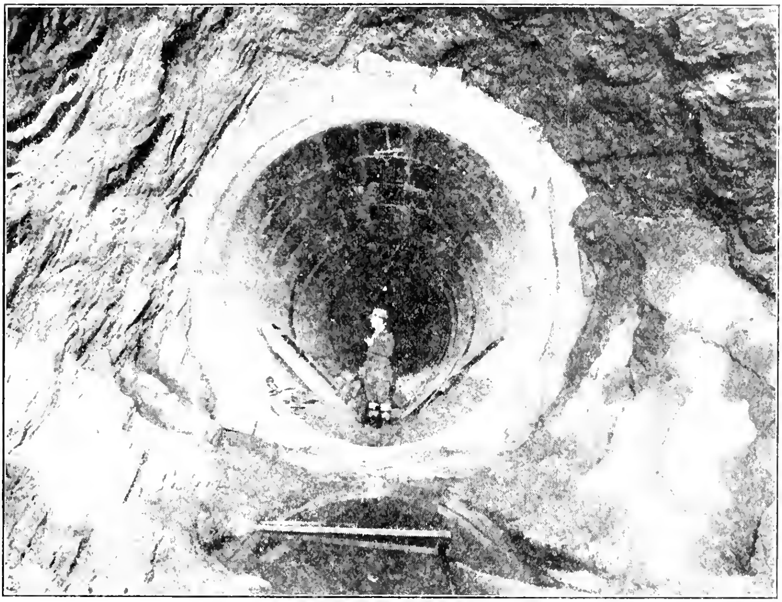


FIG. 1.—COMPLETED PRESSURE TUNNEL IN NEW YORK CITY.

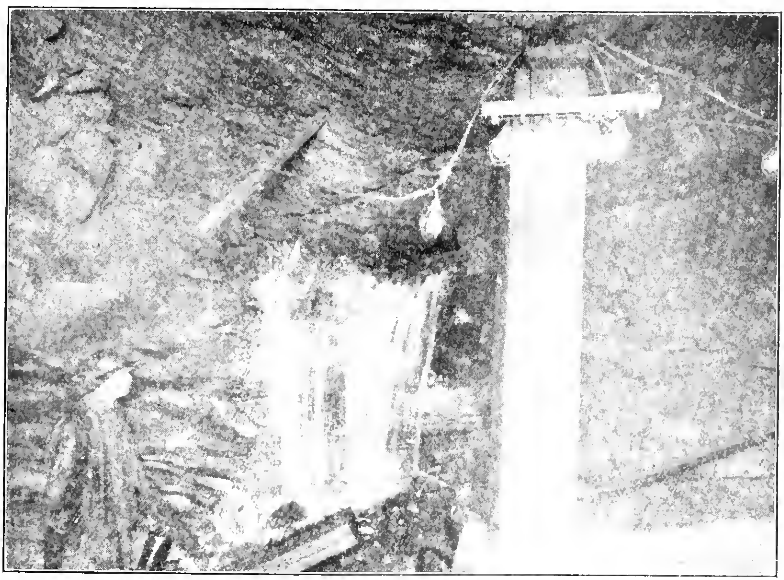


FIG. 2.—WET HEADING IN CITY TUNNEL, SOUTH OF SHAFT 4.
A FLOW OF 300 GAL. PER MIN. CUT OFF BY GROUTING.

1 100 ft., the latter being the depth at the Hudson River crossing. The hydraulic gradient at this crossing is more than 1 500 ft. above the invert of the tunnel. The pressure-tunnel type was adopted only after extended study, as there was no precedent for such tunnels subjected to such high unbalanced heads.

It was the opinion of some authorities that the concrete lining could not be made tight enough against ground-water heads. It was also feared that where the rock was porous and water-bearing, excessive leakage might develop when the tunnel was put in service, and that the application of pressure in the case of jointed and fissured rocks might even cause movement of the rock and rupture of the concrete lining, with resultant outward leakage. Great reliance, therefore, was placed on the use of grout to make the tunnels secure and tight against all leakage.

Design of Pressure Tunnels.—On account of the heavy internal hydrostatic pressures, it was deemed advisable to place the tunnels under a heavy cover of sound rock. This cover is not less than 150 ft., except in the case of comparatively light heads. On account of the external ground-water pressure on the tunnels when they were under construction, or at any time when they are out of service, the circular shape was adopted, and the lining was made thick enough to withstand both the ground-water head and the grouting pressure necessary to overcome frictional resistance and ground-water head. The concrete for the lining was proportioned, mixed, and placed so as to be practically water-tight. The concrete lining, in addition to preventing outward leakage, also provides a smooth coating to produce a high coefficient of flow. It also prevents the falling of rock and makes easier the cleaning of the tunnel.

As it was practically impossible in lining the tunnel to pack the concrete tightly against the irregular surface of the rock in the roof, grout was forced in to fill all the voids over the arch and back of the lining and to transmit the internal pressures to the rock. It was expected also that the grout would be effective in closing the seams and crevices in the rock surrounding the tunnel by impregnating any porous, water-bearing strata so as to cut off all subsequent outward leakage.

Conditions Encountered During the Excavation of the Pressure Tunnels.—Before the contracts for the pressure tunnels were let,

extensive borings were made to develop the rock profile in the valleys to be crossed and to ascertain the kind and condition of rock to be encountered during the driving of the tunnels. The tunnels penetrate a wide range of geologic formations, the rocks varying in character from a soft shale to hard quartz conglomerate. The most important quality, however, from the standpoint of water-tightness of the tunnel, was the soundness and tightness of the rock to prevent outward leakage.

In stretches where the tunnels passed through faulted and crushed zones, and the rock was either unsound or structurally weak, steel ribs and lagging were used to support the roof. At these places the space between the steel lagging and the rock was packed with stone, the dry packing being subsequently grouted through 2-in. pipes set in the concrete lining and extending into the dry packed space.

Although the pressure tunnels were excavated several hundred feet below ground-water level and under rivers and streams, there were only a few stretches where an excessive quantity of water entered during the excavation. In many stretches the tunnels passed through blocky ground intersected by joint planes and crevices; the openings in the rock at these places were often found to be filled with deposits of mineral matter, and little or no water entered the tunnels through such openings. Several of the tunnels passed underneath glacial gorges, and the drift overlying the rock formed a dense impervious blanket against the inflow of water. With the exception of the wet stretches of tunnel, to be described in detail later, no cases of inward leakage occurred during the excavation exceeding 150 gal. per min. per mile of tunnel. In the 18 miles of the City Tunnel, the maximum quantity of water which entered the tunnel, was 137 gal. per min. per mile.

The geological conditions in the tunnels were given careful consideration, as the structure of the rock, the nature of the openings, and other conditions influenced the method of grouting. Underground water circulates in the rock through the intersecting joint planes and seams formed by bending, folding, and faulting due to disturbance of the earth's crust. Stratified rocks are often found with alternating hard and soft layers, some of which are quite porous, permitting free circulation either through the body of the rock or along the bedding planes. Vertical planes of fracture are of frequent occurrence in stratified rocks. In the Helderberg limestones large solution cavities

or mud seams were encountered, requiring special precautions in making the tunnel secure and providing against subsequent outward leakage.

All inflowing water from the rock seams was taken care of before placing the concrete lining by collecting the water and leading it through pipes set in the concrete, as will be described later in detail. Subsequently, the water-bearing fissures were grouted through these pipes. In many cases, the inward leakage during excavation gradually diminished and often stopped after some interval, due to the discharge of accumulated water in the seam, but the points of inward leakage and the areas of general seepage were carefully noted when the excavation was first made. The locations of wet seams were recorded, and provision was subsequently made for grouting at these places, as it was realized that when the tunnel was in service, water could escape through the same channels whereby it had entered.

Grouting the Rock Seams During Tunnel Driving to Cut Off Leakage Into the Tunnel.

Where large flows of water are encountered in driving a tunnel, a loss of progress invariably results, and very often the work is shut down until additional pumps are installed for handling the water. Obviously, it is of great advantage to reduce or cut off the leakage, if possible, where the inflow is very heavy, before the heading is advanced. As a rule, however, superintendents dislike to stop excavation and grout the wet ground, preferring to continue the driving, if possible. Several efforts were made on this work to cut off the water by grouting the rock during excavation.

Wet Stretch, Rondout Tunnel.—In driving up a 15% incline north of Shaft 4, in the Rondout Tunnel, a faulted and crushed zone in High Falls shale and Binnewater sandstone was encountered, yielding a considerable flow of water charged with H_2S gas. To shut off the water, an attempt was made to solidify the rock in advance of the excavation by grouting through the drill holes in the heading which flowed water. These holes yielded a flow of about 300 gal. per min. They were closed with pipes and grouted, but the high pressure used—200 lb. per sq. in.—blew off 3 ft. of the soft shale in the face of the heading. Additional holes were drilled around the periphery of the tunnel and grouted. Although the leakage was somewhat reduced, the

flow increased with the advance of the heading, as additional water-bearing seams were encountered.

On account of the heavily faulted and crushed condition of the shale, which was intersected by wide and narrow seams, it became apparent, after further efforts, that grouting could not be depended on to reduce the leakage materially, and it was then decided to advance the heading without further grouting. After a suspension of nearly three months, during which time a pumping plant having a capacity of about 5 000 gal. per min., was installed in the tunnel, excavation was resumed. The first shot revealed a large water-bearing crevice to the right of the tunnel yielding about 600 gal. per min. Numerous other leaks were encountered as the heading was advanced, the total pumpage reaching a maximum of about 2 000 gal. per min. The inflow of water subsequently gradually diminished to about 1 000 gal. per min., remaining nearly constant at this figure until it was finally shut off by grouting after the lining was placed.

Better results might have been secured in this stretch if a concrete bulkhead had been used to retain the grouting pressures, although the soft and weak condition of the rock was very unfavorable for grouting. Another reason for failure to cut off the water under the conditions encountered was the difficulty of adjusting the consistency of the grout to both large and small seams. Large seams require thick grout for thorough filling, while thin grout must be used to fill the fine seams. Ordinarily, the consistency of the mix was adjusted to the large seams which have to be filled first. In order to secure the best results, grouting of the large seams should be followed by re-drilling and grouting with fine grout, to fill the narrow seams.

Grouting Water-Bearing Seam, Hudson Tunnel.—In excavating the Hudson Pressure Tunnel, 1 100 ft. below the river surface, a flow of about 500 gal. per min. was encountered in the heading near the East Shaft. A 4-in. pipe was first put in the hole from which most of the water issued, and concreted in place. The pipe was connected to the discharge line in the shaft, and the water was forced by its own pressure to a pump chamber at the side of the shaft 300 ft. above the bottom. Eight horizontal holes were drilled into the heading and plugged with pipes fitted with valves. A concrete bulkhead, 5 ft. thick, reinforced with steel rails, was then built against the face of the heading, the pipes extending through. About 180 bags of neat

cement in grout was then forced in through the pipes under pressures up to 700 lb. per sq. in. The grout was mixed in a Canniff tank and was discharged by displacing it with water pumped in by a high-pressure plunger pump.

On shooting the heading after the grout had set, there was no increase of water even after passing the seam, which was a narrow, clean-cut, vertical crack crossing the tunnel nearly at right angles and found to be well filled with grout. When the bench was excavated, exposing the seam in the bottom, it appeared to be filled with grout, but after it had been excavated about 13 ft. beyond the point of original leakage, one of the vertical bench holes struck a flow of 110 gal. per min. This flow disappeared after the next shot, and it is supposed that the hole was plugged by the displacement of the rock. The open condition of the seam in this tunnel made it easy to grout, particularly as a tight bulkhead was provided, retaining the pressure. The rock was firm and hard, and the walls of the fissure did not contain soft rock, which would have blocked the opening and prevented the free entrance of grout.

Grouting in Pressure Tunnels After Placing the Concrete Lining.

With the exception of the two instances just described, where an attempt was made to grout the rock seams at the time of driving, all grouting in the pressure tunnels was done after the concrete lining had been placed. As already suggested, the purpose of this grouting was, first, to fill with grout all void spaces between the concrete lining and the rock so that the internal hydrostatic pressures might be transmitted to the rock without rupturing the lining; and, second, to prevent or reduce the leakage out of the tunnel by forcing grout, under pressure, into the water-bearing crevices in the rock and by impregnating any porous rock surrounding the tunnel.

Placing the Concrete Lining in the Pressure Tunnels.—The concrete lining in the pressure tunnels was placed in three steps: First, the invert or bottom strip, from 4 to 6 ft. wide; second, the side-walls extending up to, or a few feet above, the horizontal diameter; and, third, the arch comprising the upper part of the section. The invert was placed continuously, with joints at the end of the day's run, which averaged about 125 ft., while the side-walls and arch were con-

creted in lengths depending on the lengths of forms used, varying from 40 ft. to a maximum of 150 ft. Steel forms were used for the side-walls and arch, the concrete being shoveled behind the forms from platforms resting upon these forms. When the concrete in the arch had nearly reached the top, longitudinal boards were set radially on either side of the top arch plate, and the concrete was banked up on a slope above the boards. Before placing the concrete in the key of the arch, the radial boards were removed and the concrete was shoveled in place in the key by end handling.

The concrete for the tunnel linings was mixed approximately in the proportions of 1:2:4 in the pressure tunnels north of New York City. The mix, however, was varied as the requirements of the work demanded. In the City Tunnel, a 1:1½:3 mix was adopted. Portland cement was used in all parts of the work. A moderately wet or plastic mix was used for the entire section, except near the top of the arch, and in the key, where a drier consistency was adopted.

Protection of Concrete from Inflowing Water During Placing.—In order to secure a dense, tight lining, it was considered essential to protect the concrete, while it was being placed and during the time of setting, from running water. The method generally adopted to accomplish this purpose was to place tin or galvanized-iron drip-pans against the rock so as to collect the water and keep it away from the concrete during placing and setting. The water from the pans ran into the tunnel through weepers, consisting of 2-in. steel or wrought-iron pipes set in the concrete while it was being placed, the pipes being extended through the steel forms by holes cut in them.

In cases of concentrated flows, holes were drilled into the rock seams and pipes were set to collect the water without the use of drip-pans, or, in some instances, both deep-seated pipes and pans were used. All flowing pipes and spaces behind the drip-pans were subsequently grouted. The drip-pans were usually held in place against the rock by nailing the edges of the pans to wooden plugs set in holes a few inches deep drilled for the purpose, and by bracing them from the forms. The space between the edges of the pan and the rock was carefully caulked with oakum or plaster of Paris, or a mixture of cement and plaster of Paris, to prevent the concrete from getting behind the pan and plugging the weeper.

In placing invert concrete, the water-bearing seams were taken care of by placing over them broken stone drains covered with cement

bags or sheets of tin, and placing grout pipes so as to have them extend down through the invert concrete and drain. Wherever necessary, the water was kept below the top of the broken stone drain by pumping through one of the grout pipes until the concrete had set sufficiently hard. In other cases, longitudinal pipe collectors were laid under the invert, carrying the water to a sump from which it was pumped. There were cases of small springs in the lower part of the side-walls, where drip-pans could not well be placed. At such places, the grout pipe was run to a blind drain made of broken stone and covered with empty cement bags and dry concrete.

The drip-pans varied in size from 1 or 2 sq. ft. to a maximum of, perhaps, 150 sq. ft. It was found to be better to use several small pans rather than one large one, in order that the grouting pressures might be applied more directly and thus be more effective in closing up the seams, and also to avoid possible rupture of the lining upon the application of the high-pressure grouting. The pans were usually fitted with two pipes, one at the bottom to drain the water and subsequently for grouting, and the other near the top to act as a vent and aid the circulation of the grout in the pan. Small pans were frequently fitted with only one pipe. A great deal of care and attention was given to the placing of the drip-pans and pipes in order to insure a tight concrete and, in addition, to make adequate provision for effective grouting subsequently.

In order to make it unnecessary to cut many holes through the forms for the pipes, it was intended originally to arrange the piping back of the forms so as to use a system of collectors with a few holes cut in the forms at regular places. It was found to be more effective, however, to use short, direct pipes for grouting purposes. There are several objections to grouting through long pipes with bends and other connections; namely, the danger of clogging the pipes, the impossibility of cleaning out the pipes or drilling through holes already grouted for the purpose of regrouting, and the delays likely to occur in placing an arrangement of pipes with complicated details.

With the steel forms first used, holes were cut for the grout pipes and weepers only where necessary, and after repeated use, the forms were badly cut up. On some of the later work, holes were cut in the forms at standard locations. On one contract there was a threaded hole at the center of each plate, to which the pipe could be secured. This

provided an opening for each 15 sq. ft. of surface, which was adequate for ordinary conditions.

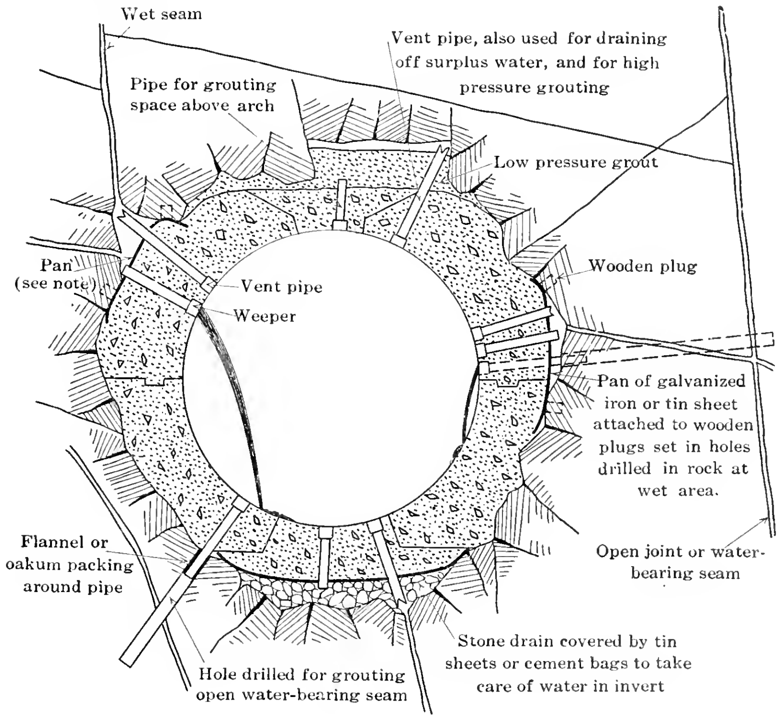
By the methods adopted for placing the concrete and protecting it from inflowing water, during setting, a dense concrete of excellent quality was obtained for the lining of the pressure tunnels. In a test made in the Wallkill Pressure Tunnel, the lining for a stretch of 180 ft. of ungrouted tunnel was subjected to a pressure of 135 lb. per sq. in. The only indications of seepage through the concrete were a few damp spots. If the concrete in the pressure tunnels had not been of good quality, it would have been extremely difficult to make the grouting operations successful.

Grout Pipes and Weepers.—In placing the concrete in the key of the arch, it is a practical impossibility to pack it tight against the rock continuously in the roof. Furthermore, in setting, it shrinks away from the rock. In order to fill the void space along the top and haunches of the arch, grout pipes were set in the arch concrete at the time it was placed. In some stretches, where the breakage in the roof was very high, the space above the normal thickness of the arch was filled with dry packing which was subsequently grouted. Where steel roof support was used, the dry packing placed between the steel lagging and the rock was also grouted through pipes set in the concrete lining.

Grout pipes in the arch were usually placed at intervals not exceeding 25 to 50 ft. along the dry stretches. In the beginning, three pipes were placed at each transverse joint in the arch, one at the center and one at either haunch, for grouting the joint. These pipes, however, were found to be of little value for the purpose and were dispensed with in later work. Additional pipes were placed at points of high breakage in the roof to serve as vents to prevent the formation of air pockets and insure the complete filling of the voids.

Both weepers and grout pipes were 2-in. steel or wrought iron, except in one of the tunnels where 1½-in. pipes were used. The 2-in. pipes are preferable as they do not clog as readily as the smaller ones. The grout pipes were carefully placed and were usually wedged between the forms and the rock, either with a spike or other spacer at the end near the rock. Each pipe was provided, at the end nearest the form, with a standard coupling to which the hose connection was made for grouting. On some parts of the work, a wad of oakum was placed in the end of the pipe nearest the rock in order to keep out the concrete.

Upon removing the forms it was the usual practice to clean out the pipes by poking a rod into them. To prevent the displacement of the pipes during concreting, it was the practice in one of the tunnels to extend all pipes, the dry ones as well as the weepers, through the forms by means of nipples screwed into the couplings. The nipples had to be removed before the forms were struck.



Note:

Water flowing into the tunnel from the seams in the rock is collected behind drip pans, and drains into the tunnel through 2" pipes set in the concrete while the latter is placed. The concrete is thereby protected from running water during setting. The 2" pipes are later grouted. Holes are also drilled in the rock before placing concrete, to intercept water-bearing seams. These seams are subsequently grouted through 2" pipes placed in the holes as shown.

PRESSURE TUNNEL
IN WET SEAMY ROCK
METHOD OF TAKING CARE OF
INFLOWING WATER AND MAKING
PROVISION FOR GROUTING
WATER-BEARING SEAMS
JUNE 12, 1918

FIG. 3.

Low and High-Pressure Grouting.—Grouting in pressure tunnels was done in two stages: (1) Low-pressure and, (2), high-pressure grouting. The purpose of the low-pressure grouting was: (*a*) primarily to fill the void spaces between the lining and the rock, particularly above the arch, and, at the same time, to form a blanket over the construction joints in the arch; (*b*) to fill the voids in the dry packing where the latter was used; and (*c*) to fill any porous or honeycombed spots in the concrete.

The object of the high-pressure grouting was: (*a*) To cut off the leakage of water into the tunnel and thereby prevent the escape of water out of the tunnel by filling with grout, forced in under high pressure, the crevices and openings in the surrounding rock; and (*b*) to complete the filling of the voids between the lining and the rock, particularly in the high places in the roof, and between the drip-pans and the rock. In general, the procedure followed in grouting was first to grout the space above the arch under low pressure through the pipes set for the purpose, and then to grout, under high pressure, the vent pipes and weepers.

Low-Pressure Grouting.

Detailed Description.—The details of the low-pressure grouting differed somewhat on the various contracts, the following description being typical of the procedure as finally developed. When a stretch of tunnel was ready for grouting, the usual practice was first to grout the arch pipes, beginning at one end of the stretch and working toward the other. The pipe to be grouted was first raked out in order to clean it of any obstruction; sometimes, it was blown out with air to clear it. Plug cocks were placed on all pipes to which connections were made. A 2-in. grout-hose connection, equipped with a side vent, was attached to the pipe to be grouted, and batches of grout from a tank grouting machine were then discharged through the hose and into the pipe, by compressed air. The pressure ordinarily used for this grouting was about 75 to 90 lb. per sq. in.

Grouting was continued at each pipe to which connection was made until the pipe refused to take more grout or until the grout had traveled along the roof several hundred feet ahead, when connection was made with another pipe and the process repeated. The distance which the grout above the arch could be forced ahead of the pipe,

varied from 200 to 300 ft., and, in some cases, where there was a large continuous void space in the roof, it would travel more than 500 ft. It was the usual practice, however, where conditions were normal, to grout the space above the arch by making connections to the roof pipes every 125 to 200 ft.

In charging the grout tank the cement, sand, and water in proper proportions were placed in the tank, and the air was allowed to boil up through the batch to agitate it, while, at the same time, the batch was generally stirred by a hand paddle, as the air alone was insufficient to mix the materials thoroughly.

As the batches of grout were forced into the pipe and the grout flowed ahead, water in large streams issued from the adjacent roof pipes; this was the excess water from the grout, as well as the ground-water leakage which had collected above the arch. This water was pushed ahead of the grout, and as soon as the pipes showed a flow of grout they were plugged either by driving tapering pine plugs into them or, as in the case of the vent or other pipes to which connection was to be made for high-pressure grouting, they were closed by means of the plug cocks at the ends. In some cases, the holes for the connections were plugged by driving a wad of oakum back into the far end of the pipe. At the end of the shift, or several hours after grouting, when the grout had partly set, the oakum was removed with an auger. Any pipe which had filled up with grout that had set, was drilled out for the subsequent grouting.

During low-pressure grouting, the high vent pipes were kept open to drain off the excess water, to permit the escape of air, and to prevent the accumulation of ground-water pressure. During the grouting, the transverse joints in the arch and any porous spots in the concrete generally showed a seepage of water first, then very thin grout appeared, after which, the leaks usually stopped in a short time, and silted up. In some cases, the leakage of grout and water through the joints was stopped by driving thin wooden wedges into the joints, and leakage through the porous concrete was stopped by bracing and wedging a board covered with a mat of oakum against the porous spot. The longitudinal joints on either side of the key at the top of the arch also leaked in a few stretches, due principally to porous concrete in the vicinity of the joints.

The weepers from drains and drip-pans, and the deep-seated pipes were also kept open during low-pressure grouting. The matter of proper venting and free drainage of the ground-water during low-pressure grouting is of the greatest importance in securing good results, because it is essential not to permit the building up of a ground-water head on the fresh grout since the object is to form an impervious blanket over the top of the arch and thereby prevent leakage of water through the unset grout and the formation of channels through the transverse and longitudinal construction joints or through any porous spots in the concrete.

Grouting Dry-Packed Spaces Above the Arch.—When grouting dry packing in large void spaces above the arch, hose connections were first made to the lowest pipes, and as the voids in the dry packing were filled and the water was drained off, connections were made to the higher pipes. Cases occurred where the vent pipes extended from 15 to 20 ft. in the dry packing above the arch, and, at these places, grouting was continued until the vent pipes showed a flow of grout, indicating that the dry packing was thoroughly filled. Where water is present above the arch, it is important that the grout should displace the water from below and not be permitted to mingle with it. Samples cut from the grout above the arch showed the grout to be exceedingly dense and impervious, filling the space without shrinkage and often forming a close bond with the surrounding rock.

Proportions Used for Low-Pressure Grouting.—A batch of grout consisted of one bag of cement weighing about 95 lb., one bag of sand weighing generally about 80 to 90 lb., and from 6 to 8 gal. of water, the total making a batch of about 2.0 to 2.2 cu. ft. of liquid grout measured in the tank. The cement was the ordinary commercial brand used for the concrete lining. The sand was very fine, screened when necessary to meet the requirements of the specifications, namely, that 100% pass a sieve having 64 openings per sq. in., 45% pass a sieve having 1 600 openings per sq. in., the wires of the sieves being, respectively, 0.035 and 0.013 in. in diameter. In the work north of New York City, glacial sand was used, while for the City Tunnel white quartz beach sand from the south side of Long Island was obtained.

The quantity of grout placed depended on the excess breakage in the roof and the extent of the dry packed spaces. In the City Tunnel, in unsupported stretches, where no dry packing was used in the roof,

the quantity of grout placed under low pressure varied from 4 to 9 cu. ft. per lin. ft. of tunnel.

Progress in Low-Pressure Grouting.—The progress in low-pressure grouting varied, usually from about 600 to 1 000 ft. of tunnel a week, working three shifts a day. Many factors influenced the speed, such as the length of haul, the delivery of materials, the proficiency of the gang in loading and unloading the cars, etc., and, of course, the volume of space to be filled above the arch. Usually, in normal stretches of tunnel, not more than one or two connections were made in 24 hours. The sand and cement were hauled through the tunnel to the grouting plant on flat cars holding from 20 to 30 bags. The sand was brought to the work in bulk, but was bagged by hand at the top of the shaft before it was sent underground. Tests were made of handling the sand in bulk in the tunnel, but it was soon found that a package of about the same size and weight as a bag of cement was the most convenient form for rapid handling.

The force employed in the tunnel for low-pressure grouting was generally one foreman and seven or eight men, two charging the grout tanks, one stirring the batch, one operating the valves on the grout tank, and three or four handling the hose and making the connections. On the surface, men were employed to bag the sand and load the cars on to the cages.

Precautions to Be Observed in Placing Low-Pressure Grout.—Low-pressure grout should be injected gently under as low a pressure as possible to avoid churning of the mix and separation of the ingredients, and only a sufficient quantity of water should be used to produce a freely flowing mixture that will not clog the hose. The air pressure should not be higher than necessary to force the grout through the hose and into place. A reducing valve was used on some parts of the work to cut down the line pressure from 90 to 40 and 30 lb. per sq. in. An excess of air, especially when injecting grout under water, is likely to agitate and churn the mix, causing separation and stratification of the sand and cement, with the formation of a soft deposit of laitance at the top of the grout in contact with the rock.

To avoid the after blast of air when grouting a space filled with water, it was the usual practice to close the discharge valve before the hose "kicked", the latter requiring careful watching. A further precaution used to prevent the separation of the mix where a large

space filled with water was grouted, was to keep the grouting connection from 2 to 3 ft. below the top of the grout.

The importance of venting the high pipes and allowing all the weepers to run freely during low-pressure grouting has been referred to. It sometimes happens that low-pressure grout enters the drip-pans or drains, but in such cases the pipes should not be kept closed to allow the accumulation of ground-water pressures.

In stretches showing general seepage in the roof of the tunnel, taken care of by drip-pans and pipes, it was sometimes found that the panning was not entirely successful in preventing the water from mingling with the grout. At first, it was thought that these wet stretches should not be grouted with the drier stretches on either side, and they were skipped on the first trip, but it was found that better results could be secured by grouting the wet stretches in the roof with the rest, as the water in the wet stretches did not accumulate pressure, but would travel over the top of the dense unset grout to open vent pipes, sometimes a long distance away, instead of breaking through the grout blanket at a point of near-by weakness.

High-Pressure Grouting.

The purpose of the high-pressure grouting, as already stated, was to complete the filling of the voids between the lining and the rocks, and, more particularly, to cut off the flow of water into the tunnel by forcing grout into the water-bearing seams and closing up all openings in the surrounding rock, in order to prevent or reduce the leakage out of the tunnel when the latter is in service.

Detailed Description.—It was the general practice first to grout the high vent pipes in the roof, in order to complete the filling of the space above the arch, and then to grout the pipes from the drip-pans and the deep-seated pipes leading to the rock seams. Some of the vent pipes in the roof showed a flow of water in stretches originally dry. The grouting of one vent pipe would often stop the flow of water from another, indicating a flow of grout through the open seams in the rock. In other cases there would be an increase in the flow of water from a weeper due to forcing water through the rock seams to an open vent. As a rule, very little grout could be injected into the vent pipes.

After grouting the arch pipes, the "wet" pipes, or weepers, were next grouted. In starting operations, air at 100-lb. pressure was

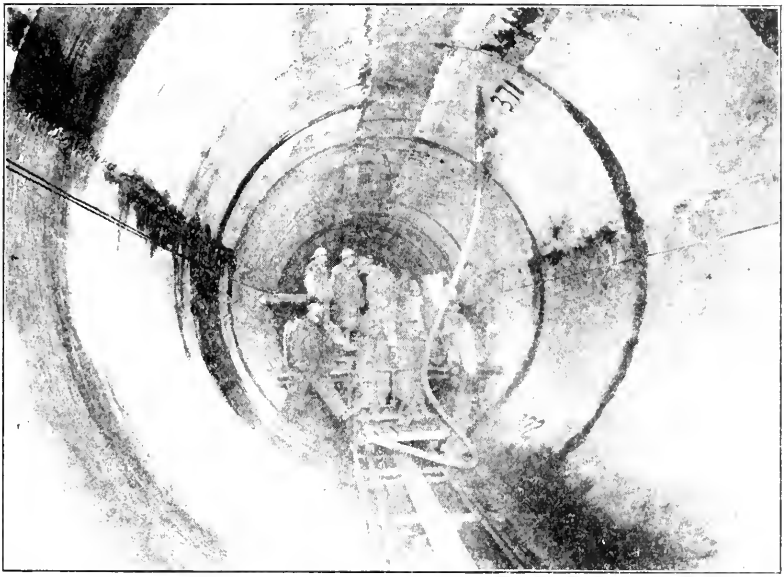


FIG. 4.—GROUTING EQUIPMENT IN OPERATION IN CITY TUNNEL.

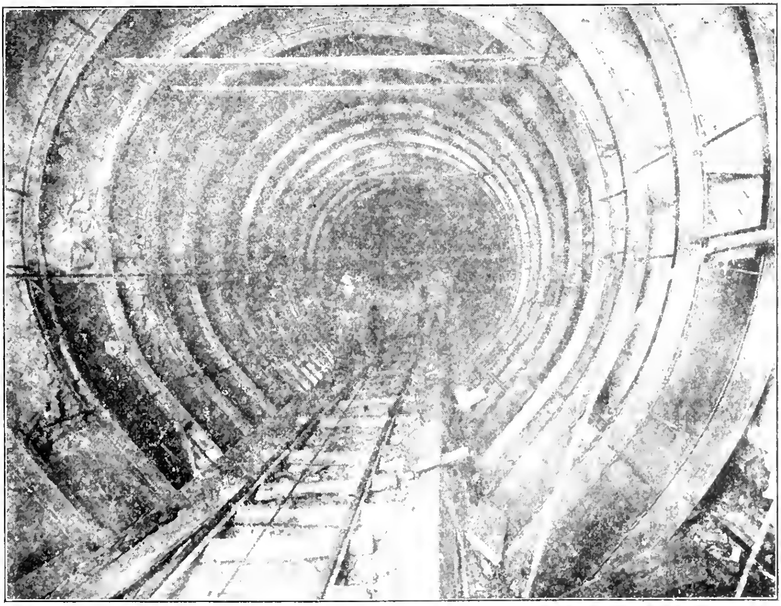


FIG. 5.—STEEL SHELL FOR TAKING CARE OF WATER, RONDOUT PRESSURE TUNNEL. FLOW OF 2 000 GAL. PER MIN. ENCOUNTERED IN STRETCH OF 350 FT.

blown into the pipe to expel the water from the drip-pans or seams. This was sometimes followed by a charge of water to clear the pipe just prior to grouting. The charge of water was often applied as a test to give an idea of the circulation of grout to be expected. If the charge of water failed to "go", the pipe would take very little grout. Another indication of the size and extent of the rock seams that could be reached from a connection was the showing of air at another open pipe or the refusal of the pipe to take air when high air pressure was applied.

The usual practice was to grout the weepers with a mix of 1 bag of cement and 5 to 8 gal. of water. When the pipe would take no more grout, the high pressure, about 300 lb. per sq. in., was kept on it for from 5 to 10 min., which had the effect of squeezing the water out of the grout and packing the cement solidly in the pipe. Frequently, if this procedure did not completely fill the pipe, it was drained and plugged with a thick batch of grout. Temporary plugging of a seam during grouting was often overcome by forcing air into the seam under high pressure.

It was found difficult to shut off small leaks through pipes set in the lower portion of the side-walls where no vents were provided. After a pressure of 300 lb. per sq. in. had been maintained on these holes for several minutes, it was often found that no grout had been forced in the pipe and the leak still continued. Such pipes were successfully closed, even in the case of those which flowed several gallons per minute, by driving a tight-fitting wooden plug into the extreme end of the pipe and then ramming with dry cement.

It was the practice on some parts of the work to complete the high-pressure grouting on all the key pipes in the arch in a stretch of tunnel, after which the tunnel was gone over a third time when the flowing pipes were grouted.

Air Pressures.—The pressure used for high-pressure grouting varied, as a rule, between 250 and 350 lb. per sq. in. This was the pressure at the grouting tank. It had to be sufficiently high to overcome the ground-water pressure and, in addition, to force the grout into the seams in the surrounding rock. In the case of very fine seams, the frictional resistance is so great that it is doubtful if much grout is injected into them even under high tank pressures.

Gauge measurements of the rock-water pressure were often taken before the grouting of a flowing pipe was started. The gauge readings, however, gave no clue as to the quantity of grout the pipes would take. The gauge pressures showed that the rock-water level at the pressure tunnels had dropped considerably below the original ground-water level, the gauges registering pressures usually under 100 lb. per sq. in., so that the back pressure was not generally high and the grout was forced in under high net pressures. In many cases, the entire ground-water head was restored a few weeks after the completion of the high-pressure grouting. The grouting of a wet seam in the Hudson River Tunnel has already been referred to. At this location, the ground-water pressure before grouting was 475 lb. per sq. in., and the grouting was done under pressures running up to a maximum of about 700 lb. per sq. in.

Mix and Consistency.—To insure the flow of grout into the fine openings, neat cement was used in high-pressure grouting. The consistency of the mix varied, depending on the conditions. Ordinarily, 1 bag of cement and 5 to 8 gal. of water were used. Where grout could be forced into the rock seams it was mixed very thin—as thin as ¼ bag of cement to 30 gal. of water. If this mix was taken freely, it was regarded as an indication that the grout was traveling some distance from the tunnel lining and, therefore, was not of much value. The mix was accordingly thickened gradually by increasing the quantity of cement in the batches until the pipe began to refuse grout, when thin grout was again injected, the pipe being finally plugged with a batch of thick grout under 300-lb. pressure.

Cement.—It was originally contemplated to use very finely ground cement for grouting in order that the grout might be carried readily into the finest seams. However, cement of ordinary fineness of grinding was used, as it was realized that, in time, the openings outside the tunnel lining and through the body of the concrete would silt up. Experiments show that the finer the grinding, the greater the loss in the strength of the grout on account of the more thorough hydration of the cement. The coarse particles impart strength to the cement, and, for that reason, very fine grinding may not be desirable. Some tests were made under severe conditions, using quick-setting Lias lime, but the results were not satisfactory, as the material did not harden properly and the water was not cut off.

Precautions to Be Observed in High-Pressure Grouting.—A very important factor in successful grouting is the control of the consistency of the mix. For large openings, thick consistencies should be used, while for the very finest openings the best results are obtained with thin grout. The thick mixes, however, must carry enough water to prevent undue clogging. No coarse particle or lumps of cement must be allowed to go into the tank. The cement is sometimes affected by the dampness of the tunnels and should be screened when necessary. Grouting of a hole must be continued without an interruption long enough to clog the hose or permit an initial set of the grout.

Special Features in Connection with Grouting.

Time Required for Grouting and Quantity of Grout Placed.—The time required for grouting the pressure tunnels varied, depending on the method and equipment used, the length of haul, the extent of the space grouted, and the quantity and distribution of inward leakage. Table 1 and the following data give the progress, force employed, power consumption, and other facts relating to the grouting in the two miles of tunnel included in Section 8 of the City Tunnel, in the lower part of New York City. This portion of the tunnel was comparatively dry, there being no large, concentrated flows within the two miles. The air used for grouting was supplied by a compressor at the top of one of the shafts. The plant and equipment used for grouting on this part of the work are shown in Fig. 6.

TABLE 1.—Data on Pressure Tunnel Grouting, Contract 67, Section 8.
Finished Diameter of Tunnel, 11 and 12 Ft.

	Low-pressure grouting: One grouting outfit.	High-pressure grouting: One grouting outfit.
Linear feet of tunnel grouted	10 313	10 313
Connections to grout pipes	170	1 683
Eight-hour shifts worked	72	116
Batches of grout placed	23 298	2 888
Quantity of liquid grout placed, in cubic yards	1 761	153
Quantity of grout per linear foot of tunnel, in cubic yards	0.17	0.02
Progress per week, in linear feet of tunnel	2 690	1 467

The total force employed in the tunnel and on the surface, averaged 42 men on each shift during the low-pressure grouting and 34 men per shift on high-pressure grouting, for two grouting outfits.

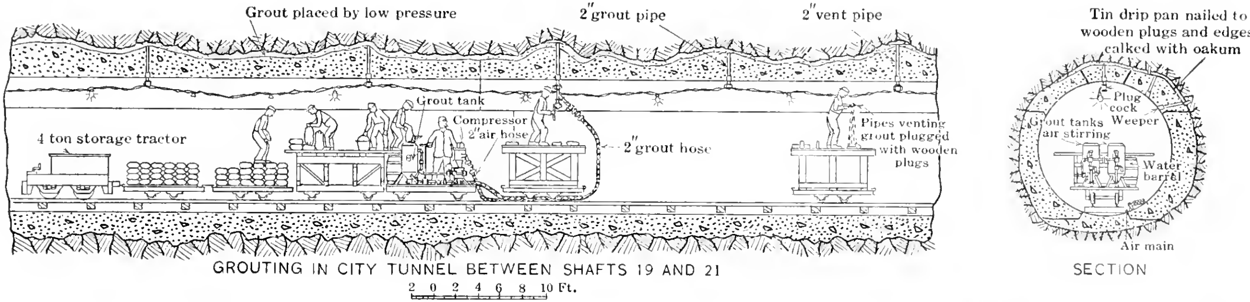
The electrical power consumed by the compressor, hoist, lighting, pumps, and tractors aggregated approximately 7 800 kw-hr. and 5 300 kw-hr. per 1 000 ft. of tunnel on low and high-pressure grouting, respectively, covering two grouting outfits.

The cost to the City, of grouting, based on contract prices, averaged $5 per lin. ft. of tunnel, on Contract 67.

Quantity of Grout Taken by Flowing Pipes.—The quantity of grout injected into the pipes varied, depending on the flow of water, the size of the openings in the rock, the back pressure, and other conditions. The quantity of water issuing from a flowing pipe gave some indication of the quantity of grout the pipe would take, but it was not an absolute index. An idea of the quantity of grout taken by flowing pipes is furnished by the experience in grouting seams in limestone in the Rondout Siphon, where the tunnel lining was ruptured on account of movement in the surrounding rock when the tunnel was first filled with water for the purpose of testing it. Holes were drilled through the lining into the rock, and the seams were grouted. A very thin grout was used—about 0.8 lb. of cement to 1 gal. of water.

In the case of 29 pipes flowing less than 1 gal. per min., only 6 took more than 1 bag of cement, and the maximum in any one pipe was $2\frac{1}{2}$ bags. Of 24 pipes leaking from 1 to 5 gal. per min., the maximum quantity of grout injected into any one pipe was 24 bags of cement, the minimum, $\frac{1}{4}$ bag, and the average, 4.3 bags. Of 12 pipes leaking from 5 to 10 gal. per min., the maximum quantity injected into any pipe was $7\frac{1}{2}$ bags, the minimum 1 bag, and the average 3.2 bags. Of 8 pipes leaking more than 10 gal. per min., the maximum quantity injected into any one pipe was 198 bags, the minimum 5 bags, and the average 62 bags.

Cut-off Walls.—The method of grouting originally contemplated called for the construction of masonry cut-off walls to be built over the tunnel arch tight against the roof, at intervals of about 50 ft. The purpose of these walls was to confine the flow of grout and to grout the space above the tunnel arch in short stretches, the pressure in the stretch grouted being raised gradually until the maximum required pressure of 300 lb. per sq. in. was reached. It was expected that the high pressures would force the grout into the seams in the surrounding rock. The cut-off walls were to be constructed so that they would retain grout under the maximum pressure.



GENERAL DESCRIPTION

The operation of grouting the tunnel was divided into two distinct stages: Low pressure grouting and high pressure grouting. The object of the former was primarily to fill the space at the top of the arch left by the shrinking of the concrete away from the rock and to fill openings at joints and honeycombed places. The object of the latter was to fill open seams in the rock surrounding the tunnel and all pipes and pans placed to control water seeping into the tunnel.

LOW PRESSURE GROUTING

Each unit consisted of a grouting car equipped with two grout tanks, one cement car, two platforms on wheels, six flat cars, two electric storage tractors and three shifts of men. Air at a pressure of 100 lb. per sq. in. at the shaft compressor was used in the machines at a pressure of 95 lb.

Only pipes located in the key portion of the arch were connected to in low pressure grouting.

The grout hose was connected to pipes situated at points where the rock roof was low; pipes at high points acted as vents. As grout flowed along the top of the arch, first water appeared through joints between successive days' work and from grout pipes embedded in the arch; this water was followed by grout which became thicker and thicker and finally clogged all leaking joints. All pipes running grout were stopped with wooden plugs and the valves on key pipes were closed.

In low pressure work the hose was connected directly to valves on key pipes instead of on the Y-branches shown. Grout was forced ahead 100 to 300 ft. before the machine was moved to the end of the grouted portion. The standard low pressure batch was 1 bag of cement, 95 lb. of sand and about 7 gal. of water. This batch made 2.04 cu. ft. of liquid grout or 1.92 cu. ft. of set grout.

HIGH PRESSURE GROUTING

Twenty-four hours after any section of tunnel had been grouted by low pressure, all pipes which were to be connected to were cleaned out to rock to allow effective treatment by high pressure grouting.

Each unit consisted of one grouting car equipped with one grout tank and one booster compressor, one cement car, two platforms on wheels, three flat cars and two electric storage tractors and generally one shift of men. Air was delivered from the shaft compressor to the booster compressor, which raised the 95 lb. pressure to 300 lb.

High pressure grouting was accomplished generally in one trip over the section of tunnel. The grout hose was connected to the pipes by a Y-branch, as shown, to allow a rod to be forced in for the purpose of freeing a passage for the grout which often became jammed in the pipes by the high pressure.

All grout pipes that were connected to had grout forced into them at 300 lb. pressure, which was maintained for 5 minutes. The standard high pressure batch was 1 bag of cement and $5\frac{1}{2}$ gal. of water, which made 1.24 cu. ft. of liquid grout or 1.2 cu. ft. of set grout.

FIG. 6.—METHOD OF GROUTING IN PRESSURE TUNNEL

In the beginning efforts were made to build these cut-off walls, but, after some experience, it was found to be impracticable to make them tight against the high pressures. Aside from this consideration, there is serious objection in the case of wet stretches to dividing the arch into short sections and at once applying high-pressure grout. If the ground-water is confined, the head builds up, and on the application of high-pressure air to the liquid grout over the arch, the ground-water will force an outlet into the tunnel through the transverse construction joints in the arch. Efforts to stop such leaks by drilling holes in the concrete lining and rock and subsequent grouting were generally unsuccessful.

After the originally contemplated method of building the cut-off walls was abandoned, an attempt was made to build grout cut-off walls and to grout in three stages, substantially as follows: A connection was made to a pipe set at a low spot in the roof profile, and grout was forced in under low pressure, generally from 30 to 40 lb., until it flowed from an adjacent pipe the upper end of which was at a higher elevation. Another low spot in the roof, about 75 to 100 ft. distant, was then grouted, and the process was continued throughout a stretch of tunnel. If any weepers showed grout during this stage, they were plugged, and the holes were reopened about 12 hours later by cleaning out the pipes with a rod. Subsequently, connection was made at these holes for high-pressure grouting.

After the grout cut-off walls had set up, the second stage consisted in grouting the sections between the cut-off walls, starting with a pressure of 100 lb. and raising it to 300 lb. per sq. in. The high vent pipes were then opened and the water that had accumulated was allowed to run off. After a stretch of tunnel had been grouted in this manner, all the valves at the ends of the pipes were opened, all plugs removed, and all pipes which were open and flowed water, were grouted under a pressure of 300 lb. After this method of grouting had been tried, it was found that more than 70% of the total quantity of grout placed was used for forming the cut-off walls. There was therefore little or no advantage in this scheme, and it was abandoned, and the method of grouting the entire space above the arch in one operation without the use of cut-off walls as already described, was adopted.

A fair degree of success was attained in the use of cut-offs in one stretch in the Rondout Tunnel, where the shrinkage space between the

concrete in the arch and the rock in the roof at the end of each section of arch was packed tight with mortar. The method of grouting was to fill the space above a section of the arch with 1:1 grout at a pressure of about 50 lb. per sq. in. and, after this space was filled, to continue forcing neat cement grout through the same connection until the hole refused to take grout at 300-lb. pressure. High vent pipes in the same section of arch were then grouted under a pressure of 300 lb. per sq. in. The conditions in the stretch where this method was used were very favorable, the arch being practically dry and the breakage in the roof regular. Not all the cut-offs proved to be tight, however, and the grout was not confined in all cases. An interesting test, showing the reduction of tank pressure, was made during the grouting in this stretch. With an air pressure of 300 lb. per sq. in. at the grouting tank, a gauge at a distance of 15 ft. from the pipe connected to, registered a pressure of 160 lb. per sq. in., the 1:1 grout over the top of the arch having been in place less than 4 hours.

In stretches of tunnel where dry packing was used above the arch continuously for several hundred feet, cut-off walls were built at intervals of from 75 to 100 ft. to avoid the flow of grout for very long distances, and to prevent the separation of the sand and the cement. Brick cut-off walls were built in connection with the grouting of the wet stretch on the incline north of Shaft 4, Rondout Tunnel. The grouting of this stretch is described in detail later.

Drip-Pans vs. Deep-Seated Pipes.—There may be a difference of opinion as to the best method of treatment in taking care of incoming water and subsequent grouting where the leakage into the tunnel extends over a considerable area. Although in numerous cases deep holes were drilled into the water-bearing seams to collect the water, it was not the general practice to drill an extensive number of such holes where large wet areas were encountered. The use of drip-pans, whereby all the open seams are exposed directly to the action of the grout, is believed to be the best method of treatment in such cases. In either method, penetration of the grout is probably very slight in the case of small openings in the rock.

In two cases where excessively wet stretches of tunnel were encountered, namely, in Rondout Tunnel, north of Shaft 4, and in the City Aqueduct Tunnel, near Shaft 24, light steel shells consisting of ribs and plates were used to protect the concrete during placing. (See Fig. 5.)

The space between the shell and the rock was dry packed and subsequently grouted. In addition, holes were drilled directly into the seams and grouted. Very successful results were obtained by the methods adopted in these two stretches. There were other places where deep holes were drilled in wet ground and grout forced in the rock with very good results. Where conditions are favorable, that is, in porous and broken-up rock with open and distinct seams, permitting the free circulation of the grout, deep-seated pipes are undoubtedly very effective in grouting the rock. A sufficient number of deep holes should be drilled, however, so as to intersect as many seams as possible.

For a short distance south of Shaft 14 in the City Tunnel, practically the whole face of the rock was dripping water. To avoid covering the entire area with drip-pans, parallel strips of pans about 2 ft. wide and a few feet apart were placed around the upper half of the tunnel. It was thought that the water would find less resistance in traveling through a few feet of fissured rock than through the newly placed concrete lining. This proved to be the case, as all the water came through the grout pipes connected with the pans. Through these same pipes the tunnel was grouted very successfully.

To test the efficacy of the grouting of the rock by means of deep-seated pipes, test holes were drilled through the concrete lining in the Rondout Tunnel and into the rock in the very wet stretch. With one exception, the holes showed a slight seepage, indicating that the grout had filled the water-bearing seams adjacent to the tunnel. In one hole, however, drilled about 8 ft. into the rock in the invert, a flow of 71 gal. per min. was struck, although 133 bags of cement had been forced into a hole about 5 ft. away during the original high-pressure grouting. This test shows that the character of the rock, the nature and size of the openings, and other conditions must be carefully studied in locating the holes for grouting. Another requisite for success in grouting the deep-seated pipes is the use of thin grout. It is also important to inject the grout continuously, so that the ground-water pressure will not force it back into the pipe or hole.

Deep holes drilled into very fine seams will ordinarily clog the seam with drill chips, making it impossible to force much grout into such seams. Experience showed that not more than one pipe in ten would permit the grouting of fine seams. Deep holes are preferable to shallow holes, as the former are more apt to intersect water-bearing seams and

take more grout. If deep-seated pipes are used along a large water-bearing seam, they should be placed generally not more than 15 ft. apart; the seams where exposed should be raked out to clear them of loose chips of rock, and the edges should be caulked with oakum or covered by a drip-pan before placing the concrete. The difficulty of adjusting the consistency of the grout, where large and small seams occur, has been referred to. Wide seams require thick grout, while fine seams are at once blocked without filling, unless the thinnest grout is used.

Time of Grouting.—The question of the time to be allowed between the placing of the concrete lining and the application of high-pressure grout was given careful consideration, particularly where the tank grouting pressure might be transmitted over a considerable area. It was stipulated in the specifications that grouting under pressure would not generally be ordered in any place until three months after placing the concrete lining at that place. This rule was generally followed, although there were cases where grouting under 300 lb. pressure was done within a month after the placing of the concrete without injury to the lining. There were two or three cases where the lining ruptured at the time of grouting, but the breaks were not due to the lack of age of the concrete. No case of cracking occurred in the top of the arch.

Other considerations controlling the time of grouting are the shrinkage and the imperviousness of the concrete. Tests show that, at the age of 1 month, concrete has developed 80% of its 3 months' strength and has acquired the greater part of its imperviousness. Shrinkage also appears to be complete in from 3 to 4 weeks. It would seem, therefore, that grouting under ordinary conditions can safely be done one month after the placing of the concrete lining.

Cracks in the Concrete Lining.—Reference has been made to the opening of the transverse joints between adjacent sections of the arch and side-walls, due to the contraction of the concrete. Irregular transverse shrinkage cracks also developed between the construction joints, even in the 30 and 40-ft. lengths of arch and side-wall. The cracks were mostly in the arch, but were quite common also in the side-wall. This cracking is due to the contraction of the concrete in cooling from a temperature of 100 to 160° Fahr. during setting, to the normal temperature in the tunnel which in summer was not much above 60° and in the winter sometimes fell below 32° Fahr. near a shaft.

The frequency of the intermediate cracks in the lining was affected by the time of year the concrete was placed. In the City Tunnel, for example, it was found that there were more cracks in the concrete placed during the warm summer months than in that placed during the winter. The richness of the concrete also may have influenced the cracking. There was some inward leakage through the intermediate cracks in the lining after the grouting in the tunnel was completed and the ground-water pressure had accumulated. Most of these leaks, however, silted up after some interval.

There were only two cases where the lining cracked during the high-pressure grouting. In the Moodna Tunnel, several breaks developed in one stretch in the side-wall concrete, the cracks extending in places into the invert concrete. Examination showed that the breaks in this stretch resulted from defective work in connection with the placing of the concrete lining, the defects being due principally to inadequate measures for taking care of the inflowing water which accumulated behind the forms, resulting in the formation of laitance and weakening of the concrete. In grouting the Hudson Tunnel, several cracks developed in the lining under a grouting pressure of 600 lb. per sq. in. On cutting out the concrete at one of the cracks, where a large drip-pan had been used, it was found that a soft deposit had formed between the pan and the rock, so that it had been impossible to fill this space effectively with grout.

Leakage Through Construction Joints.—In wet stretches some difficulty was experienced in cutting off the leakage of water into the tunnel through the transverse joints in the arch. These joints opened up, due to the contraction of the concrete caused by the drop in temperature from the time of setting to the time of grouting. Holes drilled into the joints through the concrete and grouted proved ineffective, as the running water would wash out the grout.

Various schemes were tried to make the transverse joints tight, among which were the following: Grouting grooves were formed at the end of each arch section, either by embedding a slit rubber hose in the concrete or by nailing a strip of sheet iron over a recess left in it at the joint. These grooves were grouted through pipes set in the concrete. The results were not entirely successful in cutting off the leakage. Better results were obtained by the use of steel plates embedded in the arch joints, the purpose of the plates being to provide a

water-stop as well as to retain the grout. These schemes were used only to a very limited extent at the beginning of the work, and, later, were abandoned.

Very good results were obtained in closing wet transverse joints by hand-caulking them. Grooves about $1\frac{1}{2}$ in. deep were cut along the joint and $\frac{1}{4}$-in. lead wire was hammered in. This method proved quite effective in making the joints tight.

The longitudinal joints between the invert and side-walls were found to be tight. At the joint between the side-walls and the arch some leakage occurred in the wet places. There was also some inward leakage in places at the longitudinal joints in the arch. The greater part of this leakage was due to porous concrete in the vicinity of the joint, where a relatively dry concrete had to be used, and part may have been the result of a slight opening of the joints due to the lateral contraction of the concrete.

Inspection of Grout in Place.—In order to see how effective the grout was in filling void spaces back of the concrete lining, test holes were cut in the arch concrete in several places in the pressure tunnels. Blocks of concrete about 1 ft. square were cut out in the arch, exposing the rock in the roof. It was found that the space between the top of the arch concrete and the rock was well filled with grout, and tests showed the grout filling to be dense and hard. As a somewhat dry consistency is used for the concrete in the top of the arch, this concrete when placed is likely to be porous in places; in the concrete cut out of the test holes, the grout was found to fill the voids in this concrete, and the entire block was a dense and uniform mass that was in solid contact with the rock. Test holes were also cut from the lining in the Rondout Pressure Tunnel where grout was used to fill the shrinkage space at the top of the concrete lining placed inside of a steel reinforcing shell. Here, also, excellent filling was found between the concrete and the steel.

Several opportunities were also afforded to observe the results of the grouting during the progress of the work. In grouting the wet seam in the Hudson River Tunnel near the East Shaft, already referred to, the seam, as stated, was found to be well filled with grout when exposed by the excavation. In sinking the wet shaft, known as Shaft 4, at the Rondout Pressure Tunnel, grouting was resorted to, as the shaft was deepened to cut off the inward leakage, and the sub-

sequent excavation through the grouted zone showed the seams in the rock well filled with grout. The grouting in this shaft is described subsequently in more detail.

In Shafts 22 and 24 of the City Tunnel, where the wet portions were grouted as the shafts were sunk, subsequent excavation showed that all but the very fine seams were completely filled with grout.

Reduction of Inward Leakage After Grouting.—An idea of the effectiveness of the concrete lining and the grouting in cutting off leakage into the pressure tunnels is given by the data in Table 2.

TABLE 2.—LEAKAGE INTO PRESSURE TUNNELS.

Pressure Tunnel.	Length, in feet.	Leakage into Tunnel, in Gallons per Minute.	
		Before grouting.	After grouting.
Rondout, wet stretch north of Shaft 4	350	850	3
Rondout (exclusive of above wet stretch)	23 610	290	49
Wallkill	23 390	506	75
Moodna	24 100	496	85
City, wet stretch near Shaft 23	90	325	8
City (exclusive of above wet stretch)	93 810	973	127

Hydrostatic Tests of Pressure Tunnels.—After the pressure tunnels and shafts were completed, they were filled with water in order to test their tightness. The tests in some cases were unusually severe, as the full ground-water head had not been restored at the time the test was made. At the Rondout Pressure Tunnel, the maximum unbalanced head at the beginning of the first hydrostatic test was approximately 500 ft. After the tests, the tunnels were unwatered for inspection and repairs, and the results were found to be very satisfactory, the tunnels proving remarkably tight.

Only in four places, in the 35 miles of pressure tunnel, aggregating in length about 2 500 ft., did any weakness develop, due to the yielding of the surrounding rock, causing rupture of the lining and outward leakage and making subsequent repairs necessary. In these cases, it would have been impossible to reveal fully in advance the geological conditions, particularly where the rock appeared to be sound when the tunnel was excavated, and it is believed that no amount of grouting prior to the application of the test pressure would have been adequate to consolidate the ground sufficiently to prevent the yielding of the rock. The cost of testing the tunnels and making the necessary

repairs was very much less than it would have been to make the tunnels absolutely secure by the use of steel reinforcement in the concrete lining for their entire length.

Equipment for Grouting.

Air-Stirring Grout Tanks.—Tank grouting machines of the Canniff type were used almost exclusively for grouting. These machines are very simple in construction and operation, consisting essentially of a tight cylinder provided with suitable pipe connections for introducing compressed air and for mixing and ejecting the grout. The tanks are very compact, weigh about 500 lb. when empty, and have no moving parts to wear out and be replaced. They are, therefore, particularly well suited for tunnel work. Both thick and thin mixtures can be used in them, and they are equally well adapted for high and low-pressure work. They are very efficient where large quantities of grout have to be placed.

A slight disadvantage of the Canniff tank is found when grouting fine seams under high pressure, or placing small quantities of 1:1 grout. As the process is necessarily slow there is a tendency for the cement, but more particularly the sand, to settle in the bottom of the tank and clog the openings. The use of very thin grout usually overcomes the difficulty.

As a rule, two grouting tanks were operated simultaneously in grouting the tunnel, one being charged while the other was discharging. For high pressure work, however, it was the usual practice to use only one tank. The two tanks were mounted either alone on a low flat car, or at one end of a platform car which was large enough to hold, in addition, from 20 to 30 bags of sand and cement. In some cases, an upper platform was also provided for materials. The materials were hauled through the tunnel by mules or motor trucks. The water for mixing was measured either by pails, or automatically by a tank placed at the side or above the grout tanks. High-pressure armored hose about 25 ft. long was used for grouting purposes. The plant used for grouting on the work at the lower end of the City Tunnel is shown in Fig. 6.

Operation of Grout Tanks.—The usual method of operation during low-pressure grouting, was first to put into the tank the required quantity of water, then to let the air into the tank at the bottom.

which agitated the water, and then the cement and sand were put into the tank and stirred by hand with a wooden paddle, as it was found that the air was too slow for mixing and was also wasteful. When thoroughly mixed, the door at the top of the tank was closed, the air was then admitted at the top, and the liquid grout forced out through the grout hose into the pipe connected to. The air was then turned off quickly.

Unless care is taken to close the air discharge valve the instant the last of the grout leaves the tank, an after-blast of air follows the grout, resulting in stirring it up and causing separation of the materials, and also tending to form air pockets in the space grouted. The men operating the tanks, however, soon became skilled in controlling the discharge. As an added precaution, the air-pressure gauge on the grout tank was watched closely to note the fall of pressure as the grout discharged, and the emptying of the tank was also indicated by the "kick" of the grout hose when the charge left it.

In some cases the following scheme was tried. The air valve was closed as the batch of grout started to leave the tank, permitting the air in the tank to expand and force the grout through the hose. This method, however, was slow and was not generally used. Where the grout displaced water, the ejection of the grout by expanding the air in the tank was quite effective in cutting down the after-blast of air. The tanks could be operated very rapidly. As much as 1 500 batches of 1:1 grout, equivalent to about 115 cu. yd., were placed in 24 hours, using two tanks. This process involved the handling of about 135 tons of cement and sand in the 24 hours.

High-Pressure Air Compressors.—The air for operating the grout tanks was obtained by connecting to the air line laid in the tunnel, the air pressure in the line being usually from 80 to 100 lb. In order to provide the pressures required for high-pressure grouting, small Westinghouse direct-acting single-stage air compressors, known as "boosters", were generally used. These compressors, mounted on the same car with the grout tanks, took suction from the main air line and delivered air in the tanks at a pressure of 300 lb. per sq. in. The compressors weigh about 500 lb. They are provided with air gauges registering up to 450 lb. per sq. in. A spring relief valve, capable of being set at any pressure up to 400 lb., is placed on the main discharge. Each branch of the 2-way discharge is supplied with a stop valve, a

check valve and air emergency stop valve, so that it may be closed automatically by a sudden release of pressure due to the bursting of hose or any other reason.

Independent Air-Generating Plant in Tunnel.—The grouting in the tunnel necessitated the maintenance and operation of the large compressor plant used for tunnel driving and the re-laying of the air pipe line in the tunnel, which had been taken up during the placing of the lining. In order to avoid the use of the expensive main air plant some of the contractors used small independent portable compressors in the tunnel, driven by gasoline or electricity, and mounted on cars traveling along with the other equipment. These compressors were used both for the low and high-pressure grouting.

On the work in the northern portion of the City Tunnel, low-pressure grouting was carried on with three rigs, each consisting of the following equipment: One 30-h. p. electric motor; one Ingersoll-Rand 2-stage, belt-driven air compressor, capable of delivering 170 cu. ft. of free air per min. at 100 lb. pressure and 130 cu. ft. at 350 lb.; one geared pump, with a capacity of 50 gal. per min. driven by a 7½-h. p. electric motor; two grout tanks, two water tanks, a platform car for making connections to the grout pipes, and a platform mounted on two flat cars for the cement and sand. For high-pressure grouting the same rig was used, the compressor being adjusted to deliver air at 300 lb. per sq. in.

Grouting by Air and Water Pump.—In the Hudson Tunnel, where it was necessary to use grouting pressures of 700 lb. per sq. in., a combination of air and water-pressure pump was devised. A Canniff tank was partly filled with grout which was placed under a pressure of about 300 lb. by a Westinghouse booster connected as usual with the tank. Water was then pumped into the tank through another connection by a high-pressure Cameron pump, reducing the volume of air above the grout so as to raise the pressure to 700 lb. per sq. in., if desired. The discharge valve of the tank was then opened, and the pump was kept going in order to maintain the pressure while the grout flowed slowly into the space back of the lining. This arrangement worked very successfully. The advantage of a pump with a steady flow lies in the fact that there is no after-blast of air forced through the grout.

Paddle Mixing Machines.—In a few cases, paddle mixing machines which mix the grout mechanically instead of by air, were used. The results obtained by these machines are good when they are new, but the moving parts and the stuffing boxes soon give trouble on account of wear. The bad feature of both the air-stirring grout tanks and the paddle mixing machines is the blast of air which follows the discharge of grout. As already noted, it is very important to control the discharge of air in grouting in order to secure good results.

Grouting Pads.—The specifications called for the use of grouting pads for forcing grout into any porous concrete in the lining. These pads consisted of a steel casting measuring about 1 ft. by 2 ft. 3 in., containing a rubber gasket, and mounted at the end of a 5-in. extra heavy wrought-iron pipe. In using the grout pad, it was jacked against the porous spot in the lining by screw-jacks at the other end of the column, and the grout was then forced into the pad to impregnate the concrete. These pads were not successful, as they were clumsy to handle, the area covered by the pad was too small for effective work, and the gaskets would blow out. After a few attempts, their use was given up.

Only a few porous spots occurred in the concrete lining through which grout leaked during low-pressure grouting, and it was found that the most effective method of treatment was to wedge a board faced with oakum against the porous spot. The flow of grout soon stopped and the opening closed up.

Special Grouting in Pressure Tunnels.

Grouting Wet Stretch, Rondout Tunnel.—This pressure tunnel, 4.4 miles long, was construced from eight shafts, varying in depth from 370 to 708 ft. The shafts and tunnel penetrated eight distinct formations, including shales, limestones, and quartz conglomerate. Several stretches of faulted zones and crushed rock were encountered in the excavation. Some strata were dry; others were very porous and water-bearing.

As already described, the tunnel north of Shaft 4 was driven on a 15% grade through a badly faulted and folded stretch in High Falls shale and Binnewater sandstone. The rock was porous and water-bearing, the inflow in a stretch of 350 ft. being approximately 2 000 gal. per min. at the time the tunnel was driven. The flow gradually

diminished until it was somewhat less than 1 000 gal. per min. at the time the lining was placed. The tunnel at this location is about 450 ft. below the surface of the ground. An attempt to shut off the inflowing water by grouting at the time of driving has been described.

It would have been difficult to take care of the water by means of drip-pans during the placing of the lining, as it poured into the tunnel over large areas. The plan adopted to protect the concrete during placing was to enlarge the excavation through the wet stretch in order to permit the erection of a light steel shell (see Fig. 5), inside of which a concrete lining, 24 in. thick, was placed. The shell was 175 ft. long, and consisted of circular ribs of 7-in., I-beams set 5 ft. center to center along the tunnel, with $\frac{3}{16}$-in. plates bolted to the outside of the ribs. The space between the shell and the rock, which averaged about 20 in., was packed solid with broken stone and subsequently grouted.

Most of the water entering the tunnel in this stretch was intercepted by 6-in. lateral pipes draining into an 8-in., spiral-riveted drain laid longitudinally along the bottom of the tunnel. This drain discharged through an 8-in. valve into a sump at the foot of the wet stretch. Water was also collected through holes drilled into the rock seams to depths of from 3 to 4 ft., into which 2-in. deep-seated pipes were set, which extended through the dry packing and the steel shell and drained into the tunnel. Pipes were also placed through holes in the shell to reach the dry-packed space for the purpose of grouting the packing behind the shell.

The concrete invert, which averaged about 3 ft. in thickness, was laid first on the floor of the tunnel over the 8-in. drain. The invert was placed in short stretches, 25 and 40 ft. in length, with tight wooden bulkheads and forms. Any leakage in the bottom was taken care of by pans and broken stone drains covered with cement bags. The placing of the invert was very difficult on account of the heavy flow of water from the bottom and sides of the tunnel. After the invert was placed, the steel shell was erected and the space between the shell and the rock was dry-packed at the same time. The lining was then placed inside the shell without any trouble.

Preliminary to grouting this stretch, tight brick cut-off walls were built between the shell and the roof at each end of the shell. When grouting was started, the valve at the lower end of the 8-in. drain was

closed and the valves of all the pipes leading into the dry packing were also closed. The dry-packed space was quickly filled, forming a pond of still water, into which neat cement grout was injected. Experiments previously made showed that the materials in sand grout might separate if forced in under water. The deep-seated pipes and a few pipes at the top of the shell were left open to prevent accumulation of pressure.

Grouting of the dry packing was begun at the lower end of the shell. A battery of four Canniff grout tanks was used, the grouting of both sides of the tunnel being carried on simultaneously. The space behind the shell filled gradually, the level of the grout being indicated by opening pipes at various levels. A few of the deep-seated pipes flowed grout during this operation. They were closed, but were re-opened about 24 hours later and rodded out, after which they again flowed clear water, but in a somewhat diminished volume. In the whole section the inward leakage was reduced from 850 to 540 gal. per min. after grouting the dry packing, showing that the seams had been partly closed. The grout was injected into the dry-packed space, generally under low pressure, without causing undue agitation. The final grouting was done under a pressure of 90 lb. per sq. in. at the top of the shell. A total of 7 700 batches of neat grout (1.2 cu. ft. per batch) was forced into the dry packing, requiring ten shifts.

After the grout had set a few days, the deep-seated pipes through which several hundred gallons of water per minute issued into the tunnel, were grouted, beginning at the bottom of the shell and working up. During this process, varying consistencies of grout were used, the thinnest being $\frac{1}{4}$ bag of cement (about 24 lb.) to 30 gal. of water. After applying air pressure to clean out a rock seam, the thinnest grout was used first. If a considerable quantity, 20 to 30 batches, went into the rock under comparatively low pressure (100 lb., or less), the grout was thickened, 48 lb. to 30 gal. of water being used. If a considerable quantity of this grout was injected, the mix was again thickened, this process being continued until the tank pressure necessary for injection began to rise, when the mix was thinned slightly, and grouting continued until the pipe refused under 300 lb. pressure. The pipe was then drained out and plugged with thick neat cement grout under 300 lb. pressure. The maximum number of batches injected into a pipe was 533.

The grouting reduced the leakage on the incline from 850 to 3 gal. per min., and although the level of the water in the rock reservoir, as indicated by gauge readings, rose gradually after the completion of the grouting until the original ground-water level had been restored, there was no marked increase in the quantity of water entering the tunnel. Test holes drilled through the concrete lining and shell and into the rock showed that the rock surrounding the tunnel was impregnated with grout to a considerable depth. The success of the grouting at this location was due to the use of the deep-seated pipes, and, more particularly, to the method adopted whereby the dry-packed section outside of the lining and shell permitted the grout to come in direct contact with the surface of the porous rock.

Grouting Large Mud Seams, Rondout Tunnel.—In driving the tunnel through the Helderberg limestone south of Shaft 3, Rondout Tunnel, a crushed and faulted zone containing a number of large solution cavities filled with residual clay was encountered. The two widest seams were vertical and cut diagonally across the tunnel at an angle of about 45° to the tunnel axis. These two seams were 16 and 25 ft. wide on one side of the tunnel, but much narrower on the other side. They were filled with clay and disintegrated rock and, while excavating the tunnel, were lagged with steel channels supported by steel beams and timbering. The lining at the seams was strengthened by embedding steel shells, ½ in. thick and 41 and 59 ft. in length, in the concrete at each seam. In addition to reinforcing the lining, these shells also serve to prevent outward leakage from the tunnel.

In this stretch, a horizontal seam about 3 ft. thick also was encountered, the bottom of the seam lying about 4 ft. above the finished waterway. The mud layer was removed and the space above the waterway, about 7 ft. high, was subsequently filled with concrete. Above the horizontal mud seam was an opening in which were three rows of narrow vertical pockets, extending diagonally across the tunnel. These pockets were from 2 to 6 ft. wide and ran from a few feet to 30 ft. above the roof of the tunnel. Concrete was placed up to the top of the general roof excavation and the space above, including the narrow pockets, was filled with grout through pipes set in the concrete. A total of approximately 9 000 batches of 1:1 grout was placed in this stretch, requiring 13 days of three shifts each.

Rupture of Lining and Repair Work, Rondout Tunnel.—On the completion of the tunnel and shafts, they were filled with water for a hydrostatic test. Excessive leakage developed in the Rondout Tunnel and, after unwatering it, an examination showed that the lining was cracked in three stretches aggregating in length about 700 ft. The upper half of the tunnel section appeared to be lifted from the lower portion, water issuing in large quantities through the joint at the springing line and through other diagonal cracks in the lining.

To determine whether the lining had ruptured on account of unfilled places over the top of the arch, a test hole was cut, and several holes were drilled through the concrete to the rock in the roof. The space was found to be completely filled with grout, which was intact and in close contact with the rock. The rupture of the lining was due to the movement of the rock outside of the tunnel resulting from the application of hydrostatic pressure.

The tunnel was reinforced through the ruptured stretches by steel lining built up of rings of circular segments of 15-in. 55-lb. channels. A 2-in. annular space was left between the steel and the existing concrete lining. Preparatory to placing the steel, the cracks through which water issued were caulked with lead, thereby forcing the water into pipes drilled through the lining into the rock seams.

The space between the steel shell and the old concrete lining was first grouted. Every twelfth ring of steel had eight holes placed equally around the circumference, tapped and plugged for grouting. A 1:1 grout was used under a pressure of 30 lb. per sq. in. After this grout had set for one week, the deep-seated pipes leading to the wet seams were grouted. Very thin grout, ¼ bag to 35 gal. of water, was forced in until the hole refused at 300 lb. pressure. The thin grout was then drained out of the pipe, which was sealed with a thick batch. A total of 743 bags of cement was injected through 89 pipes. The leakage in this section before repairs were started amounted to about 400 gal. per min. After all the concrete was placed and all the grouting was finally completed, it was reduced to 2 gal. per min.

To protect the steel shell against rusting, and to provide a smooth waterway, a concrete lining, averaging 6 in. in thickness, was placed inside the steel shell. To fill the space above the arch, a grout and a vent pipe were placed in each pocket formed by the projecting flanges of the channels. A thick 1:1 mixture was used for the grouting, the

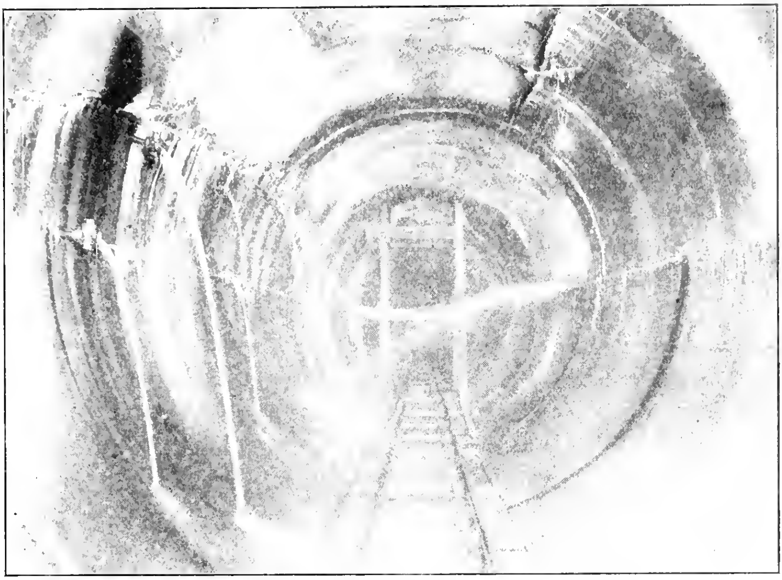


FIG. 7.—BROKEN TUNNEL LINING, RONDOUT PRESSURE TUNNEL. CRACKS DUE TO YIELDING OF ROCK. LEAKAGE REDUCED FROM 400 TO 2 GAL. PER MIN. BY GROUTING.

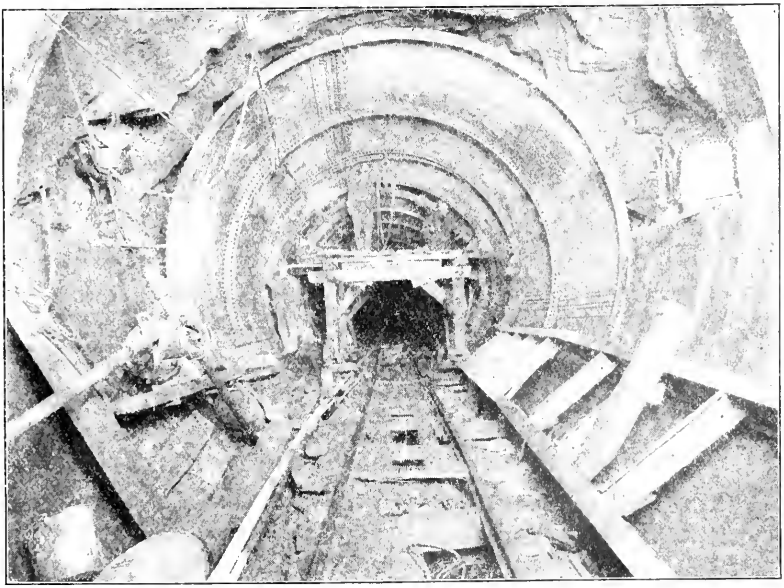


FIG. 8.—STEEL INTERLINING THROUGH DECOMPOSED ROCK, CITY TUNNEL, UNDER 106TH STREET. SPACE BACK OF LINING CONSOLIDATED BY GROUTING.

grout being placed by a Douglas hand pump. After this grout had set, and the surplus water was allowed to drain off, a second grouting was done with neat cement, completely filling the space between the lining and the steel shell.

Wallkill Pressure Tunnel.—This tunnel crosses the Wallkill Valley for a distance of 4½ miles, at an average depth below the ground surface of 350 to 450 ft. The rock penetrated was the Hudson River shale formation, and was generally sound and dry. For the greater length, the rock was a rather fine-grained shale with some beds of hard sandstone; for about a mile at the south end of the tunnel, it was mainly sandstone in very heavy beds. The dip of the rock for the greater length of the tunnel averaged about 45°, striking at an angle of about 30° with the tunnel line. At the north end, the bedding was vertical and at right angles with the tunnel axis; while for a considerable distance at the south end the beds were horizontal, causing high breakage above the roof.

The inward leakage when the tunnel was driven amounted to approximately 500 gal. per min. in the tunnel and 180 gal. per min. from the shafts. Although no great concentrated flows of water were met, certain stretches were water-bearing over large areas and the rock was extensively covered by pans to catch the water. Eight stretches of 1 000 ft. in length yielded an inward flow of more than 20 gal. per min. before grouting. The maximum inward leakage of ground-water was 90 gal. per min. for 1 000 ft. of tunnel.

In many places the water entered in fine sheets under head between the layers of shale. It was found to be practically impossible to force any quantity of grout into this rock on account of the fine openings between the thin layers. The wet areas were covered by drip-pans and grouted under high pressure with neat cement grout by filling the pans solidly full, sealing the fine openings, and effectively cutting off the water.

An interesting movement of the flow of water in the rock during grouting occurred between Shafts 1 and 2. The total leakage in this stretch just prior to starting grouting was 125 gal. per min. There was little diminution in the leakage after the low-pressure grouting, and it was not until the high-pressure grouting plant had traveled a distance of about 3 000 ft. south from Shaft 1 to within about 2 000 ft. of Shaft 2, that any marked change in the inflow occurred. In

two days of grouting, the leakage in this stretch dropped to 70 gal. per min.

Evidently, the water in a length of 3 000 ft. of tunnel, south of Shaft 1, was forced ahead during the high-pressure grouting, finding an outlet through grout pipes in the arch south of the grouting machine. There was a soft seam or plane of movement above the roof of the tunnel in this stretch, running nearly parallel with the tunnel, and apparently the water was forced through this seam during the grouting. On the completion of the grouting, the leakage in this stretch was reduced to 22 gal. per min.

Moodna Pressure Tunnel.—This tunnel is 4.8 miles long, and from 300 to 400 ft. below the surface of the ground, the maximum depth below the hydraulic gradient being about 600 ft. The tunnel penetrated Hudson River shale for about 60% of the distance and granitic gneiss for the remainder of the length. The shale was generally soft, although there were many layers of hard sandstone; the rock was much disturbed and without uniformity of attitude. The gneiss was hard and sound, but intersected in every direction by joint planes as a result of the disturbance due to a great overthrust fault which extends for many miles along the contact between the gneiss and the Hudson River shale formations.

The inward leakage for the entire tunnel, including the shafts, was 640 gal. per min. when the excavation was completed. The shale was wetter than the gneiss, but there were no large concentrated flows anywhere. Very few holes were drilled for deep-seated pipes, as practically no well defined water-bearing seams were encountered. In the shale, a drip-pan was placed about every 7 or 8 ft. of tunnel.

The rock throughout was generally firm and only 3% of the length of the tunnel required roof support. Although several zones of extensive rock movement were penetrated, there were no large openings or excessive inflows at these places, and special treatment was required in only one case, where badly crushed and unstable ground was encountered beneath the surface valley known as Pagenstecher Gorge.

In this stretch, a flow of about 100 gal. per min. was struck when the heading was first excavated. The water issued from a crevice 6 in. wide, marking a plane of movement and solution in the gneiss. The adjacent rock was crushed and disintegrated, and required a

steel roof support for a distance of 55 ft. along the tunnel. Following the first rush of water from the crevice, the leakage gradually diminished, as the underground storage was exhausted, until it was less than 10 gal. per min.

The rock broke very high and wide at this place, and, in making arrangements for grouting, long grout pipes were set to reach the top and sides of the cavity. The longest pipe extended 20 ft. above the roof of the tunnel. The dry packing between the steel support and the rock was first grouted, the operation being continued until the water-bearing crevice was filled. After the grout had settled and set, the long pipes were opened up and drained, and any remaining spaces were filled with grout under a pressure of 300 lb. per sq. in.

Repair Work in Moodna Pressure Tunnel.—The Moodna Tunnel connects at the south end with the tunnel under the Hudson River by a shaft on the west bank. Although the rock in Moodna Tunnel adjacent to the West Shaft was dense and solid when excavated, the application of hydrostatic pressure, when the tunnel was tested, caused a movement along the joint planes, with rupture of the concrete lining both in the West Shaft and in a stretch of Moodna Tunnel adjacent to the shaft. As the joint planes in the rock were closed and tight before the test pressure was applied, it would have been impossible to prevent the yielding of the rock by grouting, no matter how thorough and extensive, prior to the hydrostatic test. The cracks in the lining through which considerable water issued were subsequently caulked, and the rock was grouted. Later, it was decided, on account of the geological conditions which the test had revealed, to abandon 900 ft. of the tunnel adjacent to the West Shaft, and a new tunnel was driven 400 ft. below the old one. No further trouble was experienced at this location.

Hudson Pressure Tunnel.—This tunnel, placed 1 100 ft. below the river surface, penetrated sound Storm King granite throughout its entire length of 3 100 ft. Numerous black diabase dikes were found along the joint planes. The granite has shared with the entire Highland area in folding and faulting movements which broke up the rock into blocks separated by joint planes. In excavating the tunnel, some water from the river entered through this system of joints.

The grouting of a wet seam near the East Shaft in driving the tunnel has been described. Contrary to expectations, the leakage of

water into the tunnel was not excessive, and was taken care of in the usual manner by the use of drip-pans and deep-seated pipes. The total inward leakage after the completion of the concrete lining and prior to grouting was 160 gal. per min., the greater part occurring near the western portion of the tunnel.

As already described, some trouble was experienced in this tunnel on account of the cracking of the concrete lining in the side-walls, when the high grouting pressures, running up to 600 lb. per sq. in., were applied. After the cracks were cut out, the lining was replaced and again grouted under lower pressure, and no further trouble developed. As noted, a soft deposit was found between one of the drip-pans and the rock at one of the cracks which had been cut out, which probably prevented the filling of the space with grout. Several unusually large drip-pans were used in the wet stretches, and this may have been a factor in the cracking of the lining, as the very high grouting pressures were applied over large areas where the lining was not very thick.

No attempt was made to shut off all inflowing water in this tunnel by grouting, and the pipes which flowed water were fitted with bronze check-valves. These valves prevent the accumulation of rock-water pressure on the lining, when the tunnel is empty, by permitting the water to flow freely into the tunnel, and also, by closing tightly, prevent the loss of water from the tunnel when in service.

The high pressures necessary for grouting this tunnel were obtained by the use of a high-pressure pump which discharged the grout in the grout tank by pumping water into the tank. This tunnel proved to be remarkably tight when tested, and the loss of water when in service is very little.

Repairs in Breakneck Pressure Tunnel.—This tunnel, 780 ft. long, extends from the East Shaft of the Hudson Tunnel to an uptake shaft on the north slope of Breakneck Mountain. It penetrated the same granite formation as the Hudson Tunnel, and the rock was sound and dry. In the portion adjacent to the East Shaft, where the rock cover is comparatively shallow, cracks developed in the tunnel lining, as well as in the upper portion of the East Shaft, when a hydrostatic test was made, due to yielding of the rock along the joint planes. The lining was repaired by drilling holes about 10 ft. deep through the concrete and into the rock, and injecting thin

grout under pressure. Most of the holes took little grout, but there were a few into which a considerable quantity was forced.

The grout was mixed in the proportions of 25 lb. of cement to 20 gal. of water, and, in some cases, even thinner. Water was used for washing out the seams and frequently permitted further grouting after a hole appeared to be plugged. One hole, in the vicinity of a fractured zone in the rock, took 5 217 batches of grout containing 328 bbl. of cement. This hole was almost plugged several times, but was opened by flushing with water.

During grouting, the grout did not appear in any of the other holes in the vicinity of the pipe grouted, but was evidently forced some distance from the tunnel. Only four holes took more than 25 bbl. of cement. A total of 556 bbl. of cement was used in grouting the tunnel and 39 bbl. in the East Shaft. The repairs were successful in reducing the outward leakage to a small quantity.

City Pressure Tunnel.—The City Tunnel forms the great distribution main within the city limits. It is 18 miles long, and is located beneath the streets and parks of the Boroughs of The Bronx and Manhattan, extending from the Hill View Reservoir, just north of the city line, to two terminal shafts in Brooklyn. The tunnel was constructed from 24 shafts, varying in depth from 218 to 757 ft.

The tunnel was placed everywhere at a depth of not less than 150 ft. below the surface of sound rock. The rock is at or near the surface over the greater part of the line, and more than half of the length of the tunnel is little more than 200 ft. below the surface of the ground. In order to secure the required depth of sound rock cover over the tunnel under the Harlem and East Rivers, the tunnel was placed 330 and 700 ft., respectively, below the surface.

The formations penetrated in the City Tunnel, namely, Yonkers and Fordham gneiss, Inwood limestone, Manhattan schist and Ravenswood diorite, are generally sound and durable rocks, but were found in many places to be disturbed by folding and faulting, with extensive crushed zones. Intrusions of pegmatite were frequently met. The underground waters circulating through channels formed by mechanical fracture and solution have caused chemical changes in many stretches, with resulting alteration and weakening of the mineral constituents of the rock. For the greater part of its length, the

tunnel was driven approximately parallel with the strike of the rock, the dip being generally nearly vertical.

With the exception of two or three stretches, where heavy flows of water were encountered, the rock throughout the length of the tunnel was generally dry, and seeping water was taken care of by the methods used in the other tunnels. On account of the location of the City Tunnel, in the heart of the city, unusual precautions were taken in handling the water and grouting, in order to reduce, as far as practicable, the loss of water out of the tunnel, as it was evident that excessive leakage would be exceedingly troublesome and might result in the settlement of buildings.

Grouting under Harlem River, City Tunnel.—The tunnel under the Harlem River Valley penetrated Inwood limestone, a white crystalline marble, solid and dry for the greater part, but, for a distance of about 200 ft., a blocky stretch with water-bearing seams was encountered, yielding a flow of about 200 gal. per min. A number of large crevices, several inches wide, extended above the roof and from the sides of the tunnel. Grout pipes, some 20 ft. long, were inserted in these crevices.

All the leaks in the sides and roof of the tunnel were panned, while, in the bottom, where considerable water issued, a broken stone drain covered by pans was laid below the invert concrete. The inflowing water was drained by a longitudinal pipe on the bottom. During the placing of the invert concrete, the water was kept below the top of the stone drain by pumping through the longitudinal pipe and pumping was continued until the concrete had set.

The grouting in those portions of the tunnel adjacent to the wet stretch was completed before any leakage in that stretch was cut off. Grout was first forced into the bottom drains and pans, the upper pipes being left open to relieve the water pressure. Connections were made successively to the pipes at higher levels, until the crevices in the roof were filled. The final grouting was done under a pressure of 300 lb. per sq. in., using thick cement grout. The grouting was very successful, the inward leakage in this stretch being reduced to 3 gal. per min.

Grouting the Wet Stretch near Shaft 23, City Tunnel.—The wettest stretch in the City Tunnel was encountered near Shaft 23, where, in a crushed zone in granodiorite, a flow of 600 gal. per min., issuing from one seam, was struck when the excavation was first made. This flow

had diminished to 325 gal. per min. at the time the concrete lining was placed. On account of the large flow, it was decided to use a light steel shell to protect the concrete, instead of the customary drip-pans.

The construction was similar to that in the Rondout Tunnel and consisted of ribs built up of 4 by 3 by ½-in. angles spaced 5 ft. center to center, on which plates ⅛ in. thick were placed. Each rib was made in four segments, the bottom being embedded in the invert concrete. Where the rock showed any leakage, the space between the steel shell and the rock was filled with dry packing, elsewhere the steel plates were omitted, and the concrete lining was placed directly against the rock. Dry packing was placed over about 60% of the area in the 90 ft. of tunnel in which this special construction was used.

The water in the wet stretch was drained by a 10-in. tile pipe, laid with open joints on the floor of the tunnel and surrounded by broken stone. Above the top of the broken stone, corrugated sheet iron was placed, on which the invert concrete was laid. The 10-in. tile drain had a slope of 6 in. in 100 ft. and discharged the water into a sump at the end of the wet stretch. From the sump, the water was pumped into an 8-in. discharge line in the tunnel by a motor-driven centrifugal pump.

After all the other grouting in the tunnel between Shafts 23 and 24 had been completed, that in the wet stretch was begun by first connecting to the pipes in the bottom drain and then successively to the pipes at the higher levels, raising the grout up to a maximum of 150 lb. per sq. in. By this means, most of the grout was placed against a back pressure of 50 lb. per sq. in. or less, the gauge registering finally 90 lb. per sq. in. when the grouting plugged it.

In order to prevent the accumulation of ground-water pressure, all the pipes except those in the invert were left open, or were opened up after the grout had set. After the deep-seated pipes were grouted under a pressure of 300 lb. per sq. in., all the pipes were opened and connected to for high-pressure grouting. A total of 217 batches of neat cement grout, consisting of 1 bag of cement (95 lb.) and 6 gal. of water, was used for the high-pressure grouting in this stretch. Very successful results were obtained in cutting down the inward leakage which was reduced by grouting to 6 gal. per min. for the entire stretch of 3 600 ft. of tunnel between Shafts 23 and 24. Inspection of the tunnel after a

hydrostatic test under the operating head, showed no cracking or inward leakage in this stretch.

Repairs in City Tunnel Between Shafts 18 and 19.—The portion of the City Tunnel underneath Broadway, in the vicinity of 23d Street, was excavated through fairly sound Manhattan schist, with no inward leakage. When the tunnel was subjected to a hydrostatic test, some water appeared at the surface in Madison Square Park and in some of the cellars near-by. Although the outward leakage was not excessive, it was decided to make an effort to cut down the quantity as much as practicable. On unwatering the tunnel, it was found that, due to movement of the surrounding rock, the construction joints of the tunnel lining had opened up and, in addition, some of the lining was cracked. Four stretches of tunnel aggregating 1 350 ft. in length were affected.

The method of repair adopted was to consolidate the rock surrounding the tunnel by grouting and, in addition, to line with sheet copper two stretches aggregating about 1 200 ft. of tunnel. A large number of holes, 2 in. in diameter, were drilled through the concrete lining and into the rock, the size of the tunnel limiting the maximum depth of the holes to 10 ft. In the 1 350 ft. of tunnel grouted, approximately 10 000 lin. ft. of holes were drilled. Pieces of 1½-in. pipe, 15 in. long, were fitted into these holes.

Before grouting, grooves were cut in the joints and cracks through which water entered the tunnel and these joints were caulked with lead wire. The customary grouting equipment was used for this work, air at 90 lb. being furnished by a compressor at the top of the shaft. Higher pressures were obtained by Westinghouse "boosters".

After connecting to a hole, grouting was continued, until the hole refused grout under 300 lb. pressure. Any leaks that developed during the grouting were located, and, after the grout had set, additional holes were drilled at the place of leakage. The process of drilling and grouting a section was continued until test holes, drilled 10 ft. deep, did not leak or take grout. The stretches in which the lining was cracked were grouted three times, a portion of one being grouted five times.

The mix ordinarily used consisted of batches containing 25 lb. of cement to 20 gal. of water. If a hole into which 75 batches of this consistency had been injected, continued to take grout freely, the mix was thickened to 25 lb. of cement and 5 gal. of water; but if the hole showed

a tendency to plug, the thin mix was again used. A total of 6 000 bags of cement were used in grouting the 1 350 ft. of tunnel.

When the grouting was started, the inward leakage amounted to 30 gal. per min., practically all of which was cut off by grouting. The ground-water head against the lining during grouting, as indicated by gauges, was 78 lb. per sq. in. After the tunnel was again placed in service, there was practically no leakage at the surface of the ground.

Grouting in Shafts.

In connection with the construction of the pressure tunnels of the Catskill Aqueduct, fifty-five shafts were sunk. Some of these are permanent, forming part of the waterway; the others were sunk only to expedite the tunnel excavation, and subsequently were closed by concrete plugs. The shafts varied in depth from 106 ft. to a maximum of 1 187 ft., the average being about 400 ft.

As in the case of the tunnels, the shafts penetrated a wide assortment of rock. With a few exceptions, however, no great difficulties were experienced in sinking them, as the rock encountered was generally sound and free from large quantities of water. In some of the shafts where the inflow of water was excessive, the rock seams were grouted during sinking in order to cut off or reduce the flow. In general, the water-bearing ground did not extend to any great depth, but was found in zones about 20 to 30 ft. thick, so that, after the wet portion of the shaft was grouted and passed, no further grouting was necessary in the remainder of the shaft.

Shaft sinking is slow and expensive when large quantities of water have to be handled. The water collects in the bottom, making it troublesome to drill and to muck the broken rock, thereby delaying the work. The maintenance and operation of pumps also interferes with the excavation and increases the cost. The method of grouting water-bearing seams in a shaft during excavation, to cut off the inflowing water, has been used to some extent, although the process has been more fully developed and applied during the last few years.

The method usually adopted in grouting a wet zone is to drill a number of vertical holes in the bottom of the shaft, about 10 to 20 ft. in depth and located generally from 5 to 10 ft. around the periphery of the shaft. Short lengths of pipe fitted with valves are set into the drill holes, and the drilling is done through the valves which can be quickly closed if a heavy flow of water is struck.

After the holes have been drilled, grout is forced into the rock seams through them, by the usual grouting equipment. As in other grouting, a thick grout is best for filling large cavities, while a thin grout, as thin as 5 lb. of cement to 25 gal. of water, is necessary during the early stages of the injection of the grout, in order to make the cement carry as far as possible into the fine seams and avoid the plugging of the seams close to the drill hole. The matter of adjusting the consistency of the grout is important to insure success. After the grout has set up, and the water is cut off, sinking is resumed, using light shots to avoid opening up new fissures in the rock. The method of grouting outlined was used in sinking through wet ground in several of the Catskill shafts. The sinking in these cases would have been much more difficult, slower, and more expensive, had pumping alone been depended on.

Shaft 4, Rondout Pressure Tunnel.—This shaft, 500 ft. deep, was one of the construction shafts for the Rondout Pressure Tunnel. It was rectangular in shape and was timbered as it was sunk. This was the wettest shaft on the Catskill work, and the grouting of the water-bearing strata encountered in its excavation was very successful in cutting down the inflow of water, although pumping had to be carried on continuously during the sinking as additional wet seams were struck. A detailed description of the sinking of this shaft has been given in a paper* by John P. Hogan, M. Am. Soc. C. E.

Preliminary exploration by borings showed that the shaft would penetrate Binnewater sandstone and High Falls shale at a depth of about 200 ft. The rock cores from these beds showed a very porous condition, and pumping experiments indicated that the rocks were freely water-bearing. It is probable that considerable time would have been saved and expensive pumping eliminated during the sinking of the shaft if 4-in. holes had been drilled close together around the perimeter of the shaft when the water-bearing strata were reached, and the rock thoroughly solidified by injecting grout into the seams through these holes. The shaft could then have been excavated in the dry.

However, the drilling of the large holes necessary to insure the complete success of the grouting under such a method would have been a slow and expensive procedure, and experience at the time did not

* "Sinking a Wet Shaft", *Transactions*, Am. Soc. C. E., Vol. LXXIII, p. 398.

recommend it as the best method of meeting the situation. The handling of water by pumping was familiar to the shaft sinkers who kept on drilling and mucking until stopped by an excess of water, even though the shaft was flooded several times before the grouting was done.

The shaft was dry until a depth of 215 ft. was reached, when the water-bearing Binnewater sandstone was encountered. At a depth of 260 ft., the flow had increased to 225 gal. per min. While drilling the next round of holes, one of the holes struck such a strong flow that the men had to leave hurriedly, and the shaft was flooded to within 70 ft. of the top. The maximum flow of water entering through the drill holes in the bottom was estimated to be approximately 600 gal. per min.

After a long delay, the shaft was pumped out, and the hole in the bottom was plugged with a 2-in. nipple and gate-valve. Drilling was then resumed in the bottom, through valves on pipes set into the drill holes, the valves being shut as water was encountered. On account of trouble with the pumps and the suction and discharge pipes, the shaft was again flooded twice in succession and each time recovered.

The last holes drilled in the bottom indicated that for the next 8 ft. the ground to be excavated was very porous, with open seams as wide as 8 in. It was feared that, when the next shot was made, there would be such a great inflow of water as to flood the shaft again. It was then decided to attempt to cut off the water by grouting the water-bearing seams.

For this purpose, twenty-seven vertical holes were drilled from 14 to 20 ft. deep, around the bottom of the shaft, each hole being fitted with a pipe and valve. A total of about 3 000 bags of cement was forced into these holes. At first, the grout leaked back into the shaft, but after some experimenting, the seams were finally clogged by mixing bran, oats, and ground horse manure with the cement. This grouting was so successful that it was decided to attempt to grout the remainder of the water-bearing strata in a single operation down to the top of the Shawagunk grit, a hard quartz conglomerate encountered in sinking the lower portion of the shaft. Six diamond drill holes, 1 in. and 2 in. in diameter, were drilled around the perimeter of the shaft for a depth of 100 ft. The holes were grouted under a pressure of 275 lb. per sq. in., but only 175 bags of cement could be forced in. After further delays, due to pump troubles, sinking was resumed. In the first 15 ft. exca-

vated, numerous seams well filled with grout were encountered; the maximum thickness of the grout was 8 in., in an irregular open bed of sandstone. The leakage into the shaft at this time was 225 gal. per min., which increased to 350 gal. per min. at a depth of 280 ft. The water continued to increase in quantity to 525 gal. per min. at a depth of 320 ft., and was strongly charged with H_2S gas, which attacked the men's eyes and caused abrasions to develop into sores.

In the meantime, the pumps continued to give trouble and with the shaft filled with no less than ten of them at one time, and with air and discharge lines, it was almost impossible to carry on the sinking operations. Due to the breaking down of one of the station pumps in the shaft, the latter was flooded for the sixth and last time. After it was again unwatered, a large pump chamber was excavated in the side at a depth of 310 ft., and three steam pumps having a combined capacity of 1 050 gal. per min. were installed therein.

Sinking was then resumed (a pilot drill hole being kept well below the bottom) and all seams were grouted, none of them taking more than 50 bags of cement, until the grit was reached. At the contact with the grit, an additional flow of 125 gal. per min. entered through an old drill hole, increasing the total inflow to 850 gal. per min. The flow was cut-off by injecting 350 bags of cement under a pressure of 275 lb. per sq. in. All water-bearing seams in the grit were grouted, the maximum quantity of cement used at any point being 100 bags. When the bottom was reached, the total inflow into the shaft was 610 gal. per min.

The method of grouting used in this shaft was, in general, as follows: A 2-in. pipe provided with a long nipple and a gate-valve was driven into the drill hole as far as possible. To obtain a tight packing around the pipe, wooden wedges, oakum and cement were freely used, and horse manure mixed with the cement was also frequently used to clog the openings. A battery of four to six Canniff grout tanks was set up at the top of the shaft and connected with the hole by a 2½-in. pipe. The air pressure for grouting varied from 100 to 275 lb., the former being obtained from the main air line, and the latter from a small Westinghouse "booster." A thin mixture was used at first, and the quantity of cement was increased gradually; if this mix continued to flow freely, sand was added until the pipe began to clog.

The grouting in this shaft was very successful, at one time cutting off a leakage of more than 400 gal. per min. A total of 1 163 bbl. of cement was used in the grouting in the shaft. The holes drilled for grouting were generally 30 ft. deep, which depth was probably too great, as the grout would fill the wide horizontal seams, while the finer seams, cut nearer the bottom of the drill holes, would only be grouted for perhaps a few inches from the holes, due to the fact that in these seams the grout would set hard, while the wide seams were taking grout freely.

It is believed that the grouting would have been even more effective if shallower holes, about 12 ft. deep, had been drilled, as such holes would have cut a smaller number of seams, with the result that the rock would have been more thoroughly impregnated, and the grout would have traveled farther out from the shaft. On other work the best results have been obtained by alternately drilling and grouting, using shallow holes for the purpose.

City Tunnel Shafts.—All the shafts of the City Tunnel were lined with concrete. Although considerable leakage was encountered in several during the sinking, the inflow was either completely cut off or considerably reduced by grouting the water-bearing seams. If these wet shafts had been timbered instead of having been lined with concrete, the excavation would have been more difficult on account of the excessive quantity of water that would have had to be handled.

Shaft 4, City Tunnel.—This shaft, on the south side of Jerome Park Reservoir, was sunk to a depth of 242 ft. in Fordham gneiss. The rock was sound, and the shaft was dry until a depth of 150 ft. was reached, when a flow of 150 gal. per min. was encountered while drilling holes in the bottom. In a short time, the quantity diminished to a constant flow of about 50 gal. per min. After the shaft, which had been flooded, was pumped out, the drill holes were plugged and the concrete shaft lining was placed to within a few feet of the bottom.

The drill holes were then grouted under an air pressure of from 100 to 225 lb. per sq. in., using a mix of about 16 lb. of cement to 1 gal. of water. A total of 46 bags of cement was used in this grouting, and the leakage was entirely cut off. Water under a pressure of 70 lb. per sq. in. was also struck at a depth of 181 ft., and the flow at this level too was cut off by grouting.

Pilot holes, 14 ft. deep, were then drilled and all struck water, which in some cases washed 1-in. fragments of rock from the drill holes, indicating the presence of a disintegrated seam. These holes were grouted, but they took very little cement. The shaft was sunk another 5 ft. without increase of water. The bottom of the shaft was then in disintegrated rock well grouted.

The next step was to drill a large number of vertical holes, 18 in. apart and 16 ft. deep, around the periphery of the shaft. The holes were grouted, one at a time, each hole taking about two batches of grout, except some at one side of the shaft through which the leakage was about 100 gal. per min. The water from these holes could not be shut off, and the leakage was taken care of by pumping. As the shaft was deepened, no increase of flow was encountered, and sound rock was reached at a depth of 200 ft.

The water-bearing ground below the 181-ft. depth showed a crushed fault zone with a maximum thickness of 8 ft. on one side, below which the rock was disintegrated to a depth of 4 ft. A total of approximately 1 000 bags of cement was used in grouting this stretch, and although the disintegrated ground was found to be well impregnated with grout, the flow of water could not be entirely cut off. Thick grout was generally used, but it is believed better results might have been secured by the use of thin grout. After the shaft had been completely lined, the water-bearing seams were grouted through pipes set in the lining, and the leakage was reduced to 3 gal. per min.

Shafts 20 and 21, City Tunnel.—Shaft 20, 750 ft. deep, in the lower part of Manhattan Island, was excavated in Fordham gneiss which was generally dry. No trouble with water was experienced until a depth of 425 ft. was reached, when a flow of 30 gal. per min. was struck in the drill holes in the bottom of the shaft. Deep holes were drilled, pipes inserted, and a concrete blanket 2 ft. thick was placed over the bottom of the shaft. Grouting was started too soon, before the concrete had set hard, and it was necessary to add another 2-ft. layer of concrete. After a lapse of 48 hours, the holes were grouted under a pressure of 300 lb. per sq. in., and the water was cut off. No further trouble was had in excavating the remaining depth of the shaft.

Shaft 21 was sunk in granodiorite to a depth of 757 ft. at the East River, in the lower part of Manhattan Island. The rock was hard and

seamy, and wet zones were encountered about every 60 or 80 ft. The wet seams were grouted successfully in every case. A concrete blanket was placed over the seam to be grouted, as at Shaft 20, to retain the grouting pressures, and the results were satisfactory. The concrete lining in the shaft was placed in stretches of about 50 ft., as the sinking progressed, and any water entering through the grout pipes set in the lining was grouted off, in order to keep the bottom of the shaft as dry as possible.

Shafts 22 and 24, City Tunnel.—Shaft 22, in the Borough of Brooklyn, was sunk through gneiss and granodiorite. Only small quantities of water were handled, except at Elevation —430, where a flow estimated to have been 200 gal. per min., was encountered in a drill hole. The flow was controlled by inserting a pipe provided with a valve in the hole, after which other holes from 5 to 20 ft. deep were drilled to locate the extent of the water-bearing area, which was found to be on one side of the shaft.

The first attempt at grouting was unsuccessful, due to the large number of seams. A concrete blanket was then placed around two of the pipes, in the wet portion of the shaft, and the water was cut off by grouting under a pressure of 350 lb. per sq. in., only 6 days after it was first struck. Subsequent excavation showed that seams not more than $\frac{1}{16}$ in. wide were filled completely with cement. These seams were sharply defined cracks in the hard rock and were cut by the drill holes in such a manner as to provide good circulation of the grout, with the result that the grouting was successfully completed in a few shifts.

The granodiorite and gneiss through which Shaft 24 was sunk was blocky and more or less crushed. Little trouble was encountered in handling the water in the shaft, except in a stretch of 40 ft. at a depth of about 300 ft., where a flow of 240 gal. per min. was struck by one of the drill holes. The shaft was flooded, and it became necessary to install a large pumping plant to unwater it. After it was pumped out, the hole through which the water issued was plugged, and fourteen holes were drilled around the periphery of the shaft, varying in depth from $7\frac{1}{2}$ to $17\frac{1}{2}$ ft. Through pipes fitted into these holes, 55 cu. yd. of grout was forced into them under pressures as high as 325 lb. per sq. in.

The grouting of the wet seam caused the water to rise in the rock and flow from the smaller seams above. Holes were drilled into these seams, and grout under low pressure was forced into them, wedges of soft wood being driven into the seams where necessary to prevent the grout from escaping into the shaft. The leakage from these seams was reduced from 50 to 15 gal. per min.

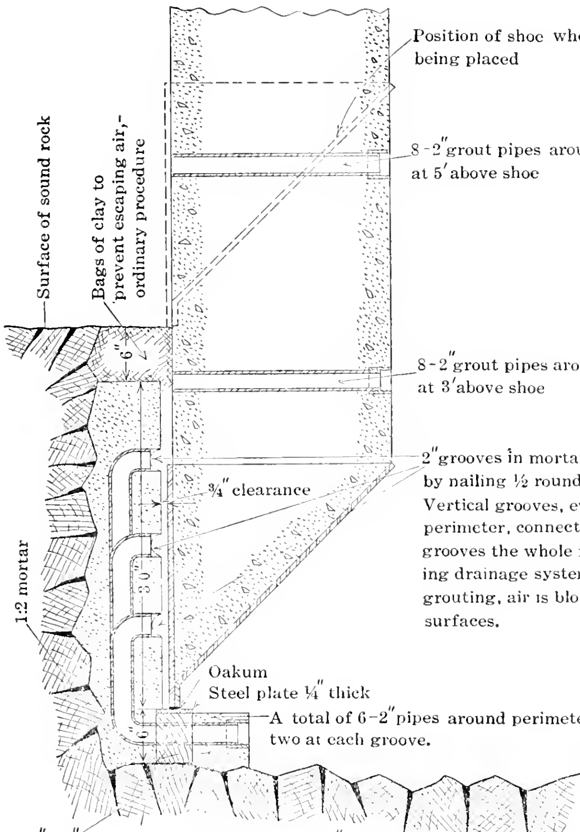
On resuming excavation, it was found that the seam which yielded the large flow had been successfully grouted and gave no further trouble, but, after the smaller seams above had been closed, the rock in the shaft sealed so badly that it was necessary to suspend sinking and place the concrete lining. The leakage remaining was taken care of by pipes set in the concrete and subsequently grouted.

Grouting Behind Caissons, City Tunnel.—Before ledge rock was reached, the six southerly shafts of the City Tunnel had to penetrate through a deposit of water-bearing sand, varying in depth from 43 to 150 ft. The earth portions of these shafts were excavated by reinforced concrete caissons sunk by compressed air.

In order to effect a tight seal at the surface of the rock, the caissons were sunk from 2 to 5 ft. below the lowest point of sound rock around the cutting edge, and the space between the caisson and the rock was grouted through pipes set in a concrete bench on which the cutting edge of the caisson was sealed. Pipes were also placed through the concrete above the bottom of the caisson for the purpose of grouting the sand surrounding the caisson. The work was successful, as the leakage from the seal, after taking off the air, was only 7 gal. per min. at the deepest caisson, that at Shaft 23, where the hydrostatic head was more than 100 ft., and, subsequently, all this leakage was grouted off.

The experience in grouting the sand behind the caissons indicated, as found on other work, that little can be done to consolidate a mass of sand by attempting to fill the voids in it by grouting, but very good results can be obtained by grouting in filling voids due to loss of ground.

Grouting Closures of Construction Shafts.—The construction shafts which were sunk solely to expedite the excavation of the pressure tunnels, were closed by filling them, for a depth of about 50 ft. above the waterway of the tunnel, with concrete. These shafts were rectangular in shape, measuring about 10 by 22 ft., and were tim-



6" x 6" wooden blocks capped with ¼" steel plate, placed at 4' intervals to receive shock of dropping caisson. Five inches of oakum placed under the entire perimeter prior to dropping, to insure water tightness. After caisson is dropped, grouting is immediately started.

3'0" collar may be reduced to 2'0" collar depending on rock conditions and ground water level.

CATSKILL AQUEDUCT
CITY TUNNEL
CONTRACT 67 SECTION 8
COMPRESSED AIR WORK
SEALING CAISSON IN
EARTH TO ROCK
SCALE ⅝" = 1'

FIG. 9.

bered. Before the concrete plug was placed, the timbering in the bottom 50 ft. was removed, and the concrete was placed solidly against the rock.

It was realized that the concrete in the plug might shrink and leave a space between it and the rock through which the water from the tunnel would escape to the surface. In order to permit the filling of the shrinkage space, grouting channels were left entirely around the shaft at the top of each lift or at vertical intervals of about 10 to 15 ft. These channels were formed by placing sheets of tin or sheet iron around the shaft, the bottom edges of the tin being left in the fresh concrete, while the upper edges were wedged tightly against the rock.

Each grouting channel was provided usually with three 2-in. pipes set in the concrete; one, acting as a vent or drain pipe, extended down to the tunnel and two were carried up to the top of the plug. The channel was kept from clogging during the placing of the concrete by flushing it with water through the pipes leading to the top of the plug. After the concrete had set and shrinkage had taken place, the channels were grouted from the top of the plug, beginning with the lower one and working up.

The usual procedure before injecting the grout was to apply air pressure to each of the two pipes leading up from the grouting channel. While one pipe was being blown out, the other was kept closed, so as to wash any water or accumulation through the down drain pipe into the tunnel. Neat cement grout was then forced into one of the pipes until it showed at the vent pipe in the tunnel; the vent was then closed, and grouting was continued until the grout flowed from the top of the other up pipe. The latter was then closed and grouting continued, until no more grout could be forced in under a pressure of 300 lb. per sq. in. The high pressure was then applied to the other up pipe, and the process was continued until all the channels were grouted.

There is some question as to whether grout can be forced into the fine shrinkage space that may develop between the concrete plug and the rock. In Shaft 3, Rondout Pressure Tunnel, where it was necessary to excavate the plug in connection with the repair work in the tunnel, there were no indications of any layer of grout between the concrete and the rock. The concrete was found to adhere closely

to the rock surface. Grouting pans are of advantage, however, in protecting the concrete from water seeping into the shaft. If the water is not collected, it will find its way through the concrete, or between the concrete and the rock, resulting in injury to the concrete or to the bond.

In Shaft 6, Rondout Pressure Tunnel, 63, 45, and 53 batches of neat cement grout were forced into the lower, middle, and top grouting channels, respectively, of the shaft plug. The total volume of grout injected, namely, 161 batches, corresponding to about 200 cu. ft. of grout, exceeded the estimated volume of space in the grouting channels, so that it is believed that some of it penetrated into the rock seams. There was also indication of this during the high-pressure grouting of the top channel. Grout appeared in the rock seams above the plug and also at the top of the plug at the contact between the concrete and the rock, 19 ft. above the top channel. The grout leaks clogged up as the air pressure was continued.

In grouting many of the construction shaft plugs, no trouble was experienced, after connecting to a pipe leading to a grouting channel, and closing all other vents, to force air either through the rock itself or through the contact between the concrete and the rock. The fact that the air pressure could be kept at 100 lb. during the previously mentioned test, or raised to a higher pressure, showed that the seams and openings were very small.

It is important while removing the shaft timbering, in connection with the placing of the concrete plug, to take down all loose rock and place the concrete against the solid rock. It is possible that the passage of air occurring during the tests previously noted, took place through loose rock seams instead of between the concrete and the rock. Not only should loose rock be removed, but also all rock that sounds "drummy" when pounded.

The concrete plugs at the bottom of the construction shafts proved to be very tight against outward leakage.

Grouting Closures in Riser Valve Shafts.—The City Tunnel shafts through which water is supplied from the tunnel to the valve chambers at the top of the shafts, are provided with riser valves which are about 100 ft. below the top of sound rock. These valves are designed to close automatically if a break occurs in the valve chamber or in the street main. Below them, the waterway is a 14-ft., or larger,

concrete-lined shaft, and, above them, the 4 or 6-ft. riser is a mortar-lined steel pipe, embedded in a solid plug of concrete forming the shaft closure. The concrete plug was placed inside of an outer shaft lining of concrete, the latter having been placed during the sinking of the shaft.

Grouting rings or channels were formed at frequent intervals, when placing the plug concrete, to permit the grouting of the shrinkage space between the new and the old concrete. These channels were grouted after the concrete had been in place a sufficient length of time to insure complete shrinkage.

The procedure in Shafts 15 and 16 was typical of the practice in the City Tunnel shafts. In these two shafts, three grouting channels were formed between the concrete plug and the outer lining, the lowest one being about 5 ft. above the point where the plug started, and the others about 10 and 20 ft., respectively, above the bottom one. The channels were formed at the end of the day's work by placing segmental timbers of 4 by 4-in. cross-section in the top of the green concrete, around the perimeter of the plug.

Two 2-in. pipes, placed diametrically opposite, were carried from the bottom of the plug to the bottom of each grouting channel. Before starting to place the next lift of concrete, the channel was covered with sheet iron bent against the outer lining and covered with a sloping layer of stiff concrete about 1 ft. thick. The latter protected the sheet iron and kept it from being displaced.

After the concrete plug had set six weeks, the channels were grouted. The general procedure in each case was to blow out the pipes and channels with compressed air at pressures of 50 to 60 lb., after which water was forced through, and, finally, grout was injected under pressures up to a maximum of 150 lb. per sq. in. The grout used varied from a mix of 1 volume of cement to 8 volumes of water to one of equal volumes of cement and water. The experience at these shafts showed a slight passage of water and grout from channel to channel, but no evidence of leakage showed around the plug at the top of the shaft.

In Shaft 24 of the City Tunnel, four grouting channels were provided in connection with the placing of the concrete plug which is 197 ft. deep and 24 ft. in diameter. To each of the two lower channels, three 2-in. pipes were carried from the shaft below the plug,

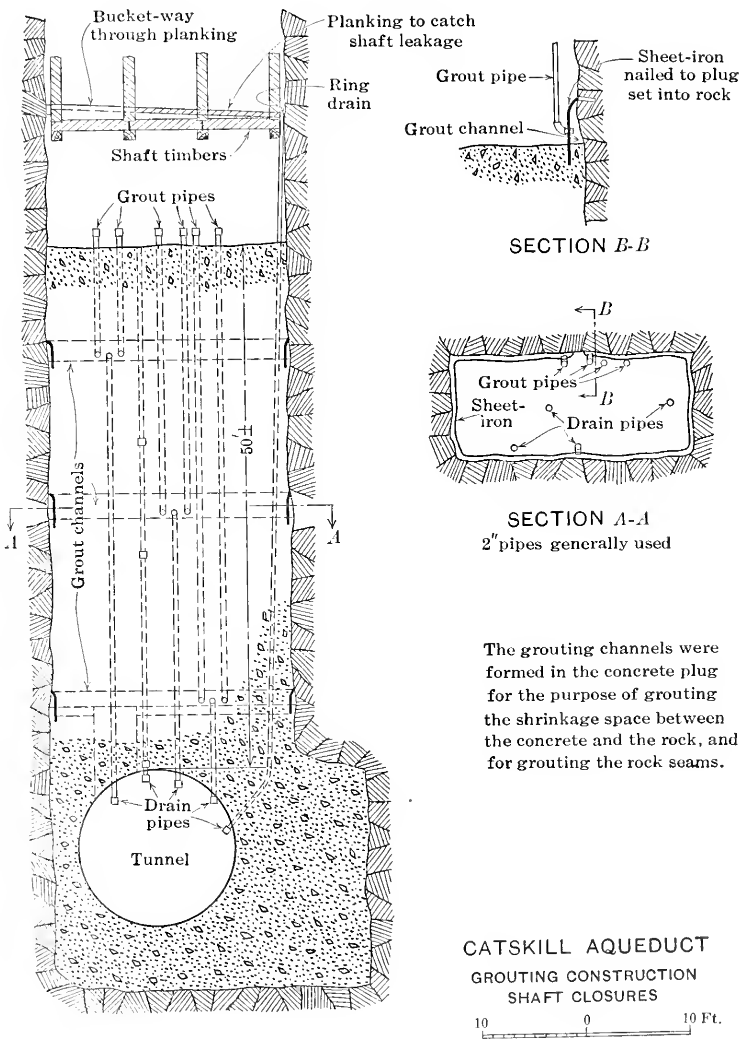

Bucket-way through planking
Planking to catch shaft leakage
Ring drain
Shaft timbers
Grout pipes
Grout channels
50'±
A
A
Drain pipes
Tunnel
Grout pipe
Sheet-iron nailed to plug set into rock
Grout channel
SECTION B-B
B
B
Grout pipes
Sheet-iron
Drain pipes
SECTION A-A
2" pipes generally used
The grouting channels were formed in the concrete plug for the purpose of grouting the shrinkage space between the concrete and the rock, and for grouting the rock seams.
CATSKILL AQUEDUCT
GROUTING CONSTRUCTION
SHAFT CLOSURES
10
0
10 Ft.

FIG. 10.

and from the two upper channels, three pipes were carried to the top of the plug. Compressed air was forced into the pipes of the lower channels before any grouting was begun. The air circulated freely between the plug and outer lining, appearing at the surface.

The bottom channel was grouted first, the grout being forced into the pipes until they refused it under 300 lb. pressure. The grout from the lower channel flowed upward into the next channel and its pipes, but reached the top of the plug through the pipes of the upper channels. Connection was made to each pipe, the lower channels being completely grouted before the upper ones were begun.

The results obtained at all the City Tunnel shafts have been very satisfactory, as there has been no leakage into any of the chambers at the top of the shafts. At some of the shafts, the pressure of the water at the level of the chamber floor is about 110 lb. per sq. in.

Grouting Under the Foundations of Dams and Dikes.

Grouting Seams in Rock Under Olive Bridge Dam.—The masonry portion of this dam is about 1 600 ft. long, and rises to a maximum height of 210 ft. above the bed of Esopus Creek. The bluestone layers underneath the creek were excavated to sound rock at a maximum depth of about 25 ft., and, in addition, a cut-off trench about 20 ft. wide was excavated, to a maximum depth of 40 ft., across the creek channel just below the up-stream edge of the dam. Below the top layer of bluestone, alternating layers of slate, shale, and bluestone were found, the beds varying in thickness from 1 to 15 ft.

Before excavation for the dam was started, the rock underlying the foundations was explored by means of fifteen diamond drill borings from 40 to 100 ft. deep, put down in the bed of the creek and the adjacent rock sides. The holes were tested by hydrostatic pressure tests for the purpose of locating the position and permeability of the seams in the rock. These investigations showed two definite planes of leakage at depths of 40 and 60 ft. below the bed of the creek.

To prevent the flow of water through the open seams, a total of 217 holes, 2½ in. in diameter, were drilled to about 1 ft. below the seams for the purpose of grouting them. The lower seam was reached by a row of 45 holes, spaced about 5 ft. apart, drilled from the bottom of the cut-off trench. For grouting the upper seam, seven rows containing 172 holes, also spaced 5 ft. apart, were drilled from the bottom

of the excavation down stream from the cut-off trench. A model was made, showing the position of the grout holes and the water-bearing seams, and was found to be useful in connection with the subsequent grouting.

A 3-ft. length of 2-in., wrought-iron pipe, the lower end of which was chipped with a chisel and wrapped with jute, was driven into the tops of the holes until the jute became firmly wedged and made a tight joint. The pipe was then wedged fast at the top with two small iron wedges, and the annular space between it and the sides of the drill hole was filled with grout, thus sealing the pipe in the hole. If water was flowing from the drill hole, the iron wedges and the grout were omitted, and dry cement was rammed into the top of the hole outside the pipe.

Sections of pipe of convenient length were successively screwed to the tops of the grout pipes so as to keep them always above the top of the cyclopean masonry as the latter progressed, until the holes were grouted. After the surface of the rock was covered by a sufficient weight of concrete masonry to overcome the possibility of lifting or blowing out by hydrostatic pressure, the tops of the grout pipes were connected to a Cockburn grouting machine of about 4 cu. ft. capacity, and grout was forced into the hole by an air pressure of from 25 to 90 lb. per sq. in. The grout generally used was mixed in equal volumes of neat cement and water.

The grouting extended over a period of about one year and was done at any convenient time after the concrete had attained a height of 10 ft. or more. The 45 holes extending to the lower seam took a total of 251 cu. ft. of grout, of which it was estimated that 175 cu. ft. entered the seam. The 172 holes drilled to the upper seam received a total of 1 118 cu. ft. of grout, of which it was estimated that 925 cu. ft. entered the seam.

The quantity of grout forced into any hole varied from 0 to 198 cu. ft., and only about 10% of the total number of holes took an appreciable quantity. The maximum distance through which grout was forced, making its appearance in other pipes, was 70 ft.

A number of experiments were made in connection with the grouting, which are of interest. Grout was forced under a pressure of 25 lb. per sq. in. into a hole drilled about 15 ft. back from the edge of the cut-off trench, and appeared on the face of the trench from a

horizontal seam about 6 in. below the top. Several months later, the rock covering this seam was barred and wedged off, and the seam appeared to be well filled with cement which was set hard.

Grout was also forced into a drill hole about 6 ft. back from the face of the cut-off trench, through two seams to the face of the trench. Two days later the rock was barred off, exposing the seams which were found to be well filled for a distance of 4 ft. in every direction from the hole, and partly filled 2 ft. farther out.

Grouting at Woodstock and Glenford Dikes.—These two structures close the gaps between the hills forming the Ashokan Reservoir. The dikes consist of rolled embankments with center concrete core-walls which, with the exception of short portions, were carried down to ledge rock. In the vicinity of the dikes, the rock is overlaid with a cover of clay and gravel, varying from 1 to 30 ft. in depth.

As the East Basin of the reservoir filled, it was observed that some seepage was taking place underneath the dikes, which increased as the water level in the reservoir rose. Although the loss of water was not serious, it was considered advisable to take measures to stop the seepage and to improve the character of the foundations. To determine to what extent this might be accomplished, it was decided to grout a portion of the foundation of the Woodstock Dike.

Operations were limited to a length of 379 ft., the total length of the dike being approximately 2 500 ft. Holes were drilled, spaced about 12½ ft. apart, on the center line of the dike where the core-wall extended to rock, and on a 5 or 6-ft. off-set line up stream from the center line, where the core-wall was not carried down to rock. Thirty-five holes were drilled, their total depth through the embankment and earth cover aggregating 426 lin. ft., while the depth of the core-borings totaled 717 lin. ft.

Where the holes were on the center line of the dike, a 4-in. casing was driven to the core-wall, a distance of approximately 9 ft. A 3-in. hole was then drilled into the core-wall to a depth of 2 ft., into which a 2½-in. casing was driven and grouted, giving a tight seal. The 4-in. casing was then withdrawn. For the holes up stream from the core-wall, a 2½-in. casing was driven to rock. The rock was chopped out to a depth of from 4 to 24 in. and the casing was driven tightly into it.

The core-borings were made with an "A" bit, which cut a hole of approximately 1¾-in. diameter. The rock encountered was bluestone,

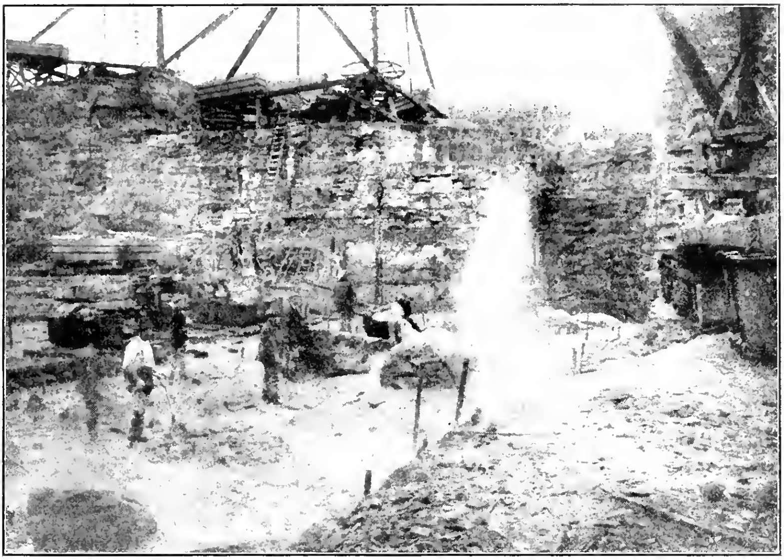


FIG. 11.—GROUTING SEAM IN ROCK, 60 FT. BELOW THE CREEK BED, UNDER OLIVE BRIDGE DAM.

FIG. 12.—MORTAR LINING IN STEEL PIPE SIPHON, 2 IN. THICK, PLACED BY POURING GROUT FROM SURFACE.

varying from a coarse stone of good quality to a very fine grained stone. In general, the holes averaged 40 ft. in depth, 20 ft. of this being in rock. Tests made by pumping water into the holes showed loss of water at practically all those drilled in rock, the maximum quantity that could be pumped into a hole without accumulating pressure, having been 66 gal. per min.

On the completion of the drilling, the holes were grouted. Two Cockburn-Barrow grout machines were used to mix the grout, discharging into a wooden box, from which it was pumped by a Douglas hand grout pump into the hole to be grouted. The mix varied in consistency from ½ bag of cement and 40 gal. of water to 5 bags of cement and 40 gal. of water. The general method of procedure was to attach the grout pump to a hole and continue pumping in grout as long as the hole would take it. In the majority of cases, the grout did not show in adjacent holes. In one instance, however, it appeared in a hole 37 ft. distant from the one grouted.

On the completion of the grouting of the rock, the casing was first pulled about 12 to 18 in., and grout was then pumped in, keeping the pressure at a maximum of 7 lb., except that after work had been done on a hole and then resumed after an interval, a slightly higher pressure was used for a short time. When the hole would take no more grout, the casing was pulled another 18 in., and the grout applied once more to refusal. This procedure was continued, alternately pulling casing and grouting, until the casing had been raised so that the bottom was at the elevation of the flow line.

The maximum quantity of grout forced into a hole in the rock was 1 078 bags of cement and the minimum 13 bags. The maximum quantity forced into a hole in the earth cover above the rock was 496 bags and the minimum 20 bags. A total of 1 881 bbl. of cement was used in this experimental grouting. It resulted in an appreciable reduction in the amount of seepage for the portion of the dike treated. Measurements made soon after the completion of the grouting, indicated a reduction of approximately 50% in the amount of seepage.

In view of the satisfactory results obtained in grouting the experimental section, it was decided to grout the foundations of the Woodstock and Glenford Dikes for their entire lengths, except a few sections which it was thought unnecessary to treat.

A modification was made in the procedure originally followed. Where the core-wall was founded on rock, the holes were drilled in two rows, 2 ft. apart, spaced about 20 ft., center to center, in each row, the holes being staggered. In the Woodstock Dike, the holes were drilled through the core-wall and into the rock, the method of sinking and sealing the casing being the same as that described in the experimental work. At the Glenford Dike, it was impossible to drill holes through the core-wall because of the location of the Ulster and Delaware Railroad on that dike; the casings, therefore, were sunk up stream from the core-wall, with the same spacing as described previously.

For the portions of the Woodstock Dike where the core-wall was not carried to rock, holes were placed on offsets and spaced 5 ft. apart; 4-in. casing was sunk to rock, and, at alternate holes, $2\frac{1}{2}$-in. casing was placed inside the 4-in. casing and securely sealed into the rock. The holes through the core-wall and into the rock were $2\frac{1}{16}$ in. in diameter instead of $1\frac{3}{4}$ in., as in the experimental work, and were drilled to a minimum depth of 20 ft. into the rock. The total linear feet of holes drilled at Woodstock Dike, including the experimental section, was 11 182, and at Glenford Dike, 9 190.

The same general procedure was followed in grouting the holes as in the experimental grouting, but some changes were made. In order to economize in the labor incidental to the use of hand-pumping of grout, water pressure supplied by steam pumps was substituted for the Douglas hand pump, four grouting units being in operation at all times, with piping extending the full length of both dikes. As before, Cockburn-Barrow grout machines were used for mixing the grout, wooden troughs conveying it to hollow iron cylindrical pressure tanks.

These grout tanks consisted of 12-in. iron pipes, 4 ft. long, laid horizontally, two of which were mounted on a portable wooden truck. Suitable 2-in. pipes and fittings made it possible to use each tank alone or in sequence. Pressure, when required, was applied at one end by connection with the water line, and the grout in the tank was discharged by displacing it with water. This method was found to work very smoothly, resulting in a saving of time and more effective grouting on account of the continuous operation.

The grouting of the earth cover and embankment above the rock, at the Woodstock Dike, was completed before the rock was grouted. The row of 4-in. casing without the inner 2½-in. pipe, was grouted first, and then the other row, the grouting of cover to flow-line elevation being accomplished by raising the 4-in. casing as desired. After this cover grouting was accomplished, the 2½-in. casing was used to grout the rock. A total of 7 564 bbl. of cement was used for grouting at Woodstock Dike, including the experimental section, and 5 613 bbl. at Glenford Dike.

The results of the grouting at both dikes have been very satisfactory, the estimated reduction in seepage, with a full reservoir, being 75% at Woodstock Dike and 90% at Glenford Dike. In addition, the foundations under the dikes have been improved materially, due to the consolidation of the disintegrated rock and the filling up of the seams and cavities.

Grouting the Foundation under Kensico Dam.—Kensico Dam is a gravity structure of cyclopean concrete masonry, with a maximum height of 310 ft. above the bottom of the excavation. The dam is across the Bronx River, between parallel ridges which rise to a height of about 180 ft. above the bed of the river. At the site of the dam, the quality and attitude of the rock was developed by core-borings which clearly revealed the geologic structure of the valley floor.

The east ridge is composed of gneiss, the west ridge of schist, and between the two hills lies a bed of crystalline limestone about 400 ft. thick. The excavation for the dam was carried down to generally sound rock. The limestone was found to be deeply decayed in places, especially along the contact with the gneiss, where the decay follows the contact for a depth of more than 100 ft. below the general level of the rock floor and affects the adjacent gneiss. No decay was found at the contact between the limestone and the schist. Both the gneiss and the schist showed less depth of decay than the limestone but, in places, these rocks were shattered and showed the effect of crush zones by lines of weakness along the bedding planes.

The foundation of the dam required more or less extensive grouting at three points, one in the schist near the west end of the dam, one at a soft seam in the limestone, and the third covering the entire east side of the gorge.

At the west end of the dam beyond the cut-off trench, the mica schist was found to contain occasional cross-bedding seams, and the area was explored by a few drill holes, 25 ft. deep, which were tested with water under pressure. Some intercommunication was found in these holes, although holes drilled in the bottom of the cut-off trench just east of this area were tight. The area was treated by drilling two lines of holes 11 ft. apart, with a 3-ft. spacing in each line, and 25 ft. deep, for a length of 40 ft. along the dam. After the masonry had been placed to a sufficient height, the holes were filled with grout under pressure.

At one place a crush zone in the limestone crossed the foundation. At the surface of the rock it was about 15 ft. wide, but it narrowed with depth. It was followed down by the cut-off excavation until it was less than 3 ft. wide, and as it was entirely filled with compact material, further excavation was deemed to be unnecessary. Holes 25 ft. deep were drilled over the area, and on testing with water and uranium, those to the west of the seam were observed to be more or less in communication with each other. When the masonry in the dam had been placed, providing a cover of 35 ft. or more in thickness, the holes were grouted.

On the east side of the gorge, where a disintegrated zone was found at the contact between the gneiss and the limestone, more extensive grouting was necessary than elsewhere. The rock lay in beds about 2 ft. thick, and when exposed the bedding planes opened up. Several layers were excavated until fairly sound rock was reached but, under exposure to the air and summer heat, a further opening of the bedding planes took place. The excavation of the cut-off trench, which was carried down to a depth of 40 ft. below the general level of the excavation, had shown that several seams in the rock were open and water-bearing.

Holes, 25 ft. deep and about 25 ft. apart, were drilled normal to the inclination of the strata, and 2-in. pipes were fitted into them and extended up through the masonry. Two rows of holes were also drilled in the bottom of the cut-off trench near the sides, about 15 ft. apart, longitudinally. The tops of the lower holes in the gorge were at about Elevation 65, and as they were not grouted until the concrete had reached Elevation 192, the grout pipes were in some cases 125 ft. in length.

Pressure tests, using water colored with uranium, were made on each hole to determine the influence on the other holes. As a result of the tests, it was concluded that the cut-off trench effectively intercepted the more open seams, and that the grout pipes could be divided into three groups: First, the holes up stream from the cut-off trench, where they all appeared to connect freely with each other; second, the holes in the cut-off trench which evidently penetrated a region not reached by the others; and, third, all the holes down stream from the cut-off trench, which were evidently quite freely intercommunicative.

In grouting, each of the three groups was treated separately. Usually, the pipe which took water most freely was the first to be grouted. As the grout appeared in other pipes, they were capped, and the pressure continued until the hole refused to take more grout. Then the pipe was capped, and connection was made to another pipe, the uppermost pipe being left open for a vent. Eventually, all the pipes were filled with grout, capped, and left embedded in the dam masonry. With the reservoir full for two years, there has been no indication of any leakage on the down-stream side of the dam.

Miscellaneous Grouting.

Mortar Lining Inside of Large Steel Pipes.—Steel pipe siphons were used for crossing valleys along the line of the aqueduct where the rock was not sound or where, for other reasons, pressure tunnels would be impracticable. The steel pipes vary from 9 ft. 6 in. to 11 ft. 2 in. in diameter, and are lined with 2 in. of cement mortar, enveloped with concrete, and covered with an earth embankment.

The mortar lining was placed in two operations (see Fig. 12): First, an invert about 8 ft. wide was placed in the bottom of the pipe, using a 1:2 mortar and finishing with a screed board and trowel; and, second, the portion above the invert was lined by using a wooden form built up of curved panels inside the pipe, and pouring grout from the surface of the ground through vertical 2-in. pipes screwed to the top of the pipe at 15-ft. intervals, one pipe being used to grout a 15-ft. section and the next for a vent.

The grout was mixed by hand on the surface in boxes arranged so that one batch would be mixed while the other was discharged. The grout was poured through the pipe screwed into the lower hole, until it ran out of the 4-ft. riser inserted in the upper hole. The pouring

was continued for some time to allow the air to escape. This method permitted the discharge of the surplus water and laitance, and effectively took care of any shrinkage. The grout for the portion between the invert and the springing line was mixed 1:1, while, for the portion above the springing line, a 1:2 mixture was used.

In one of the siphons, the mortar lining was placed by the cement gun, without the use of forms. The apparatus consisted of a double tank with air-tight bulkheads and a revolving feed for sand and cement. The mixture was discharged by air under 40 lb. pressure through a rubber hose. As the mixture reached the nozzle, it came in contact with water discharged through another hose, and the combined spray was discharged with great force against the inside surface of the steel pipe. Although the results obtained with the cement gun were satisfactory, it was not found to be well adapted for the work and was not used subsequently in the other siphons.

Grouting Expansion Joints in Cut-and-Cover Aqueduct.—The concrete in the arch of the cut-and-cover aqueduct was placed in lengths of 30, 45, 60, and 75 ft. The vertical expansion joints at the ends of the arch sections were formed either by tongue-and-groove joints cast in the concrete, or by steel plates. Owing to temperature changes, these joints opened up in cold weather, the width of the openings varying from about $\frac{1}{32}$ to $\frac{1}{4}$ in., depending on the temperature of the air and on the length of the arch sections. Hydrostatic tests, made by filling portions of the aqueduct, showed that neither the tongue-and-groove nor the steel-plate expansion joints were tight against outward leakage in all cases. After some experiments and tests, it was decided that the most effective method of making the joints tight was to grout them with cement. Accordingly, the joints in several miles of aqueduct were treated by grouting them in the winter months when they are open the widest. Only the joints that were appreciably open were grouted.

The following method of grouting was found to be successful on one section of the work. The grout from a 2-qt. tin coffee-pot was poured into a small tin funnel and through a $\frac{1}{2}$-in. rubber tubing, about 12 in. long, into the joint. The joints were usually raked out in advance of the grouting, using a 12-in. pruning saw having very coarse teeth on one edge. The grout was poured near the top of the

joint, from the inside of the aqueduct, the leakage of grout into the aqueduct being stopped by caulking the joint, usually with oakum.

Where the joints were wet, on account of inward leakage due to ground-water, it was necessary to grout them by pressure, using a Douglas hand pump for this purpose. They were first drilled by hand at convenient points, and into the holes were inserted $\frac{3}{4}$-in. pipe nipples, 6 in. long, threaded at one end. The nipples were caulked into the joints with lead wool, and the inside edges of the joints were also caulked with the same material.

The mix generally used for grout poured into place was 5 parts of cement to 8 parts of water by volume. This consistency was found to be a little too thick for the hand pump and, for the wet joints, a mix consisting of 3 parts of cement to 8 parts of water was used. The grouting was very effective in making the joints tight against leakage.

Grouting Caving Ground in the Grade Tunnel.—In driving one of the headings of the Reynolds Hill Tunnel, several slips occurred, and, in a 15-ft. stretch, the timbering was badly distorted by the slide. In order to excavate safely the bench through this section, the space outside the timbering which had previously been dry packed, was grouted. Concrete was first placed back of the timbering for a height of about 4 ft. above the wall-plates and, at each end of the section, concrete cut-off walls were built as high as possible between the lagging and the rock, the closures being made with brick masonry. The dry-packed space over the arch between the cut-off walls was then grouted by a tank grouting machine. More than 30 cu. yd. of 1:1 grout were placed. No trouble was experienced subsequently in excavating the bench through this section.

Grouting in Tunnel Where Concrete Lining Had Disintegrated.—Some time after it was placed, the concrete lining in a portion of the Eastview Grade Tunnel was found to be undergoing a progressive, slow disintegration, caused by the infiltration of the surrounding ground-water which contained certain chemical elements injurious to concrete. The portion of the tunnel affected, a stretch of about 1 700 ft., was relined with brick 12 in. thick.

To take care of the water seeping through the concrete lining, sheets of steel were used throughout the side-walls and arch of the lined section, and kept uniformly away from the concrete face by

ordinary spruce plaster lathe, to provide drainage and grouting space. Before the brick lining was placed, a bituminous water-proofing fabric was deposited on the sheet metal water-stop and on the invert concrete.

Along the center line of the invert, in the lined section, a 4-in. tile pipe was laid with open joints to receive the drainage water. Transverse drainage grooves cut in the invert conveyed the water from behind the metal stop to the center line drain. This drain was provided with 2-in. pipes, 12 in. long, extending up through the brick lining on the invert. Before grouting the space behind the water-stop, this drain and the connecting grooves were pumped full of grout, connections being made to the 2-in. pipes in the invert.

For grouting between the metal stop and the original concrete lining, 2-in. pipes were set, extending through the brick work at three levels on both sides of the tunnel. The grouting was done in successive upward stages, grout being supplied to the lower middle and upper level of pipes until it appeared at the next higher level, each stage covering the entire length of lined section before the next stage was begun. A Douglas hand pump was used to place the 1:1 grout which was mixed in boxes carried on flat cars and stirred continually while being used. On account of the hydrostatic pressure behind the brick lining, the side-walls were braced throughout the length of the lining during grouting, with 4 by 6-in. struts, spaced 5 ft. on centers, and wedged in place.

In addition to relining a portion of the tunnel with brick, additional precautions against the disintegrating effect of the ground-water were taken by grouting the space above the arch for the entire length of the tunnel, about 1 mile. This space in the roof between the concrete and the rock had been partly dry packed at the time the concrete lining was originally placed.

The grout pipes were 1½ in. in diameter, provided with couplings at their ends, and placed in holes drilled through the concrete. A pair of pipes, one a grout and the other a vent pipe, was placed through the arch concrete at intervals of about 50 ft. The inner ends of all pipes were wrapped smoothly with cotton cloth in order to make them fit tightly in the holes, and were driven in place by a sledge-hammer.

The grout, consisting of 1 bag of cement, 1 bag of sand, and usually 12 gal. of water, was placed by means of a Canniff tank, the

grout being forced in to refusal under about 90 lb. pressure. The quantity of grout placed averaged ½ cu. yd. per lin. ft. of tunnel.

General Conclusions in Regard to Grouting.

The experience in the grouting operations in connection with the Catskill Water-Works, showed that grouting is very effective for backing up, and filling the spaces behind, tunnel linings. A mixture consisting of 1 bag of cement, 1 bag of sand, and from 6 to 8 gal. of water, was found to be well adapted for this purpose. The air pressure should not be greater than is necessary to force the grout into place. The pressures actually used varied from 30 to 90 lb. per sq. in. To complete the filling of the voids between the tunnel lining and the rock, particularly in the high places in the roof adjacent to the "vent" pipes, air pressures up to 300 lb. per sq. in. and neat cement grout were used.

Good results were obtained in cutting off the leakage of water into the tunnels by grouting the water-bearing seams. For this purpose, it is essential to control the inflowing water by collecting it behind drip-pans or a steel shell, and draining it by pipes through which the grout is subsequently forced into the seams. Neat cement grout, about 6 gal. of water to 1 bag of cement, was found to be effective for this purpose. For fine openings a very thin mix must be used in order to obtain good results. The pressures should be sufficient to overcome the ground-water head and force the grout into the rock.

In sinking wet shafts, grouting was successful in cutting off leakage. The best results were obtained by alternately drilling and grouting, using holes about 10 to 15 ft. deep in the bottom of the shaft. The consistency of the grout should be adjusted to the size of the seams. In some cases, a little addition of bran, oats, etc., to the neat cement grout will aid in plugging the crevices in the rock.

The results obtained in treating the foundations of dams and in cutting off leakage underneath the dikes by drilling holes and grouting the rock seams under the dam structures were satisfactory. It is desirable in such cases to explore the rock under the dams thoroughly by diamond drill borings for the purpose of locating weak zones and open seams. The location of the holes and method of grouting will depend on the natural conditions encountered.

In conclusion, it should be stated that the procedure to be adopted in any grouting operation must take into account all the factors that enter into the problem. No one method is applicable to all cases. The conditions encountered during the grouting may make it advisable to modify the procedure materially. Good judgment and skillful adaptation to meet varying conditions are essential to a successful conclusion.

This paper was prepared at the suggestion of the Chief Engineer, J. Waldo Smith, M. Am. Soc. C. E., to whom the writers are indebted for advice and many valuable suggestions. Many of the data were obtained from reports and contributions by members of the staff of the Board of Water Supply of New York City, and the writers wish to express their appreciation of the assistance given them, particularly by A. D. Flinn, Robert Ridgway, G. G. Honness and M. H. Freeman, Members, Am. Soc. C. E., L. White, Assoc. M. Am. Soc. C. E., and Mr. L. B. Stebbins.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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THE "LIGHT RAILWAYS" OF THE BATTLE FRONT IN FRANCE

By Frank G. Jonah, M. Am. Soc. C. E.*
To be Presented Marh 3d, 1920.

Synopsis.

This paper describes the most recently developed method of transportation in the advance sector of an army.

The organization and execution of this work in the American Army was almost entirely in charge of engineers from civil life, many of whom were members of the Society. The object of this paper is to describe their activities and to present to the Profession one feature of the many engineering works that were executed so successfully by the Americans in France.

The following notes are the results of the writer's experience and observation in the construction and operation of "Light Railways" while acting as Major of the Twelfth Engineers (Railway), U. S. A., assigned to the British Army, and serving on the Picardy front (see Fig. 1) from August 21st to October 27th, 1917, and from that time until December 16th, 1918, as Chief Engineer of the Department of Light Railways of the American Expeditionary Forces.

The "Light Railway" was a development of the great war, and was gradually extended in scope and importance until, at the close of hos-

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings,* and, when finally closed, the papers, with discussion in full, will be published in *Transactions.*

* Formerly Lt.-Col., Engineers, U. S. A., St. Louis, Mo.

tilities, the mileage of the lines ran into the thousands. These railways were among the principal agencies of transportation, having been, in fact, the link between the standard-gauge lines and the trenches.

It was found by the British, in 1916, that the transportation of supplies, necessary for the dense concentration of men at the front, could not be accomplished satisfactorily on the highways, and that some supplementary means of conveyance were necessary; therefore,

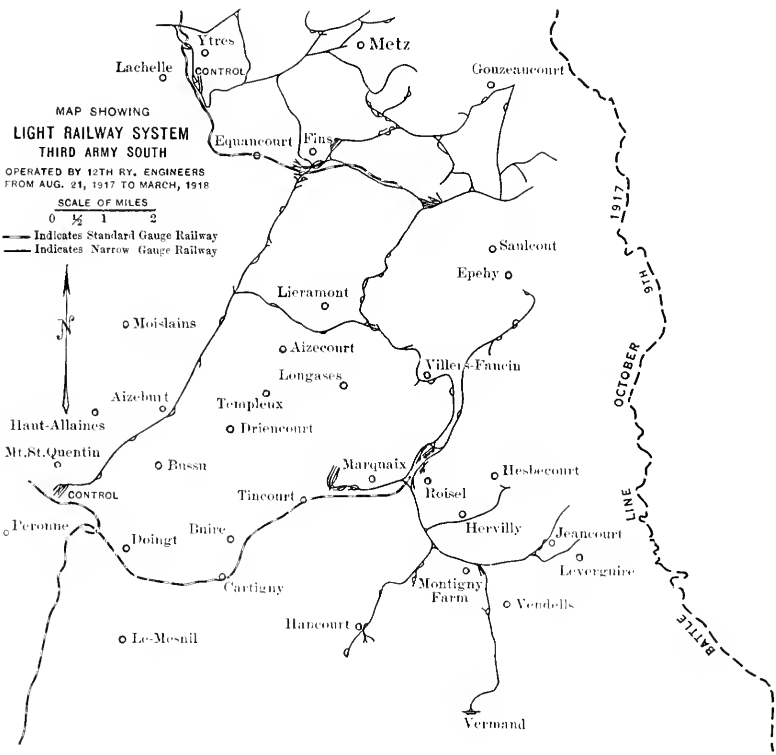

FIG. 1.

orders were given for the development of a comprehensive system of "Light Railways" for the following primary reasons:

1st.—To relieve the highways of traffic. In addition to the wear and tear on motor transport and the excessive use of gasoline, the wear on the roads was leading to a heavy traffic in road material, so that a large part of the traffic hauled by motor trucks was road material (crushed stone or gravel)

PLATE I.
PAPERS, AM. SOC. C. E.
JANUARY, 1920.
JONAH ON
"LIGHT RAILWAYS" OF THE BATTLE FRONT.

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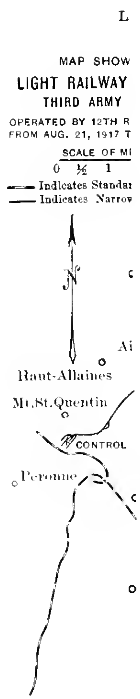

orders were
"Light Rail

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to repair the damage which their own traffic was creating; and, consequently, there would be a great saving in labor in maintaining the roads if other means of transportation were developed.

2d.—To assist in a rapid advance over shell-torn areas when the roads were useless for motor transport and little better for horse transport.

3d.—To convey road material for the rapid repair of roads in the destroyed zones.

4th.—To reduce manual labor at the front.

The lines were developed so completely that, eventually, nearly all heavy material was transported by the "Light Railways", leaving the highways clear for light, fast-moving automobiles, trucks, and ambulances.

The rail-head, or terminus, on the standard-gauge line was usually 8 or 10 miles back of the front line—far enough to be out of range of the enemy's ordinary shell fire. Between the rail-head and the front, the standard-gauge line was generally destroyed by enemy operations, oftentimes as he retreated.

At the rail-head were concentrated the supplies for a certain sector, consisting of ammunition, rations, forage, road material, building material, fuel, barbed wire, fence pickets, concrete material, culvert pipe, plank, track material, tools—in short, everything necessary for the sustenance of troops and for their means of offensive and defensive operations; and it was the function of the "Light Railways" to carry these supplies to the forward battery positions and front line trenches.

The lines were also used in moving troops up to the front, bringing back the relieved troops to their rest areas and the wounded from the front, and extensive use also was made of these lines in salvage operations. The extent to which they were developed can be readily expressed by stating that for every mile of front which an army held, there were ten miles of light railway supplying it.

The gauge of track used by all the armies on the Western front, including the German Army, was 60 cm. (23⅝ in.), usually laid 2 ft. by the British and Americans. There was great advantage in this uniformity of gauge, as it permitted interchange of equipment among the

Allies and the immediate use of the captured German tracks after successful offensives.

In a general way, the characteristics of the lines on the different army fronts were similar. Grades of 3% and curves with a radius of 30 m. were freely used to facilitate rapid and easy construction. Embankments were made with 9-ft. crown cuts, with a 14-ft. base at sub-grade.

The French track was of built-up sections, 5 m. long, the rail weighing 9 kilos per meter, with steel ties, 1 m. long, riveted to the rail,

The British used a rail weighing 20 lb. per yd. A certain amount of track was laid in short sections bolted to steel ties, but the greater part was laid with rails at least 24 ft. long, on wooden ties, 4 by 6 in. by 4 ft. 6 in., as it was found that track laid on wooden ties was much more easily kept in line and surface than that laid on steel ties.

The American track was generally constructed on wooden ties, of rail weighing 25 lb. per yd., in 30-ft. lengths. A certain amount of track in built-up sections, with a rail, 5 m. long bolted to steel ties, was kept on hand for use at the extreme front. Sections of track in this length could be handled by a squad of men and coupled up without making any noise, and consequently were preferable for work near the trenches. Such sections also had advantages when building at night.

The German lines were built with rail weighing about 17 lb. per yd. on steel ties, bolted to the rails. They were extremely well built, and by reference to the map (Plate I) showing the "Light Railways" on the Verdun and St. Mihiel Sectors, it will be seen that they had a greater mileage than the French and American Armies. Their extensive use of these railways was due to the fact that they were short of rubber tires and gasoline, and could not depend on motor transport to the extent that the Allies did; but they were in a position to develop steam railway transportation, as they held the coal and steel districts of France and Belgium.

The Germans had one type of built-up track, which had some advantages. One end of the 5-m. section had a pair of bars with a hooked projection, while the other end had the flange of the rail bent up. In laying track, the hooked bar engaged the bent-up flange of the last section. This enabled the track to be connected on the grade with great rapidity and without noise. Details of this track are indicated in Plate III.

PLATE II.
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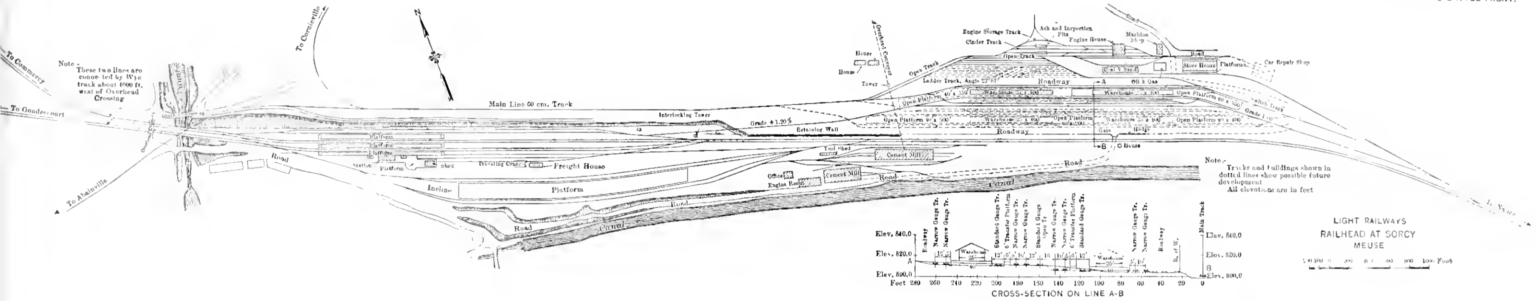
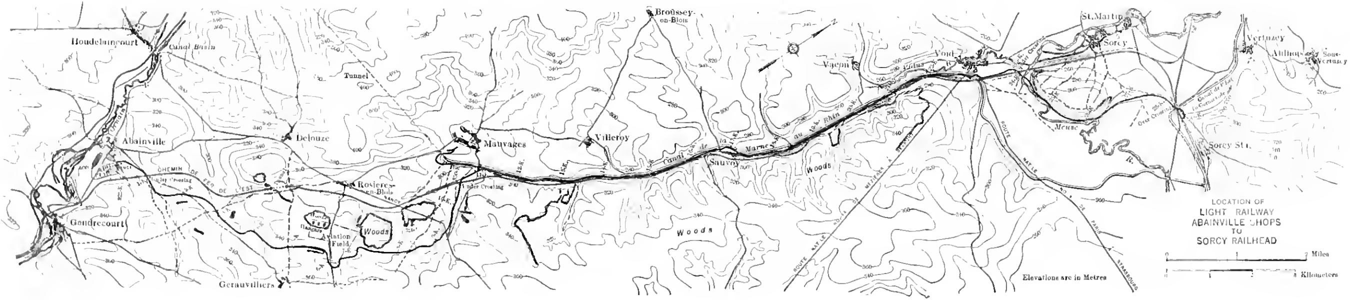
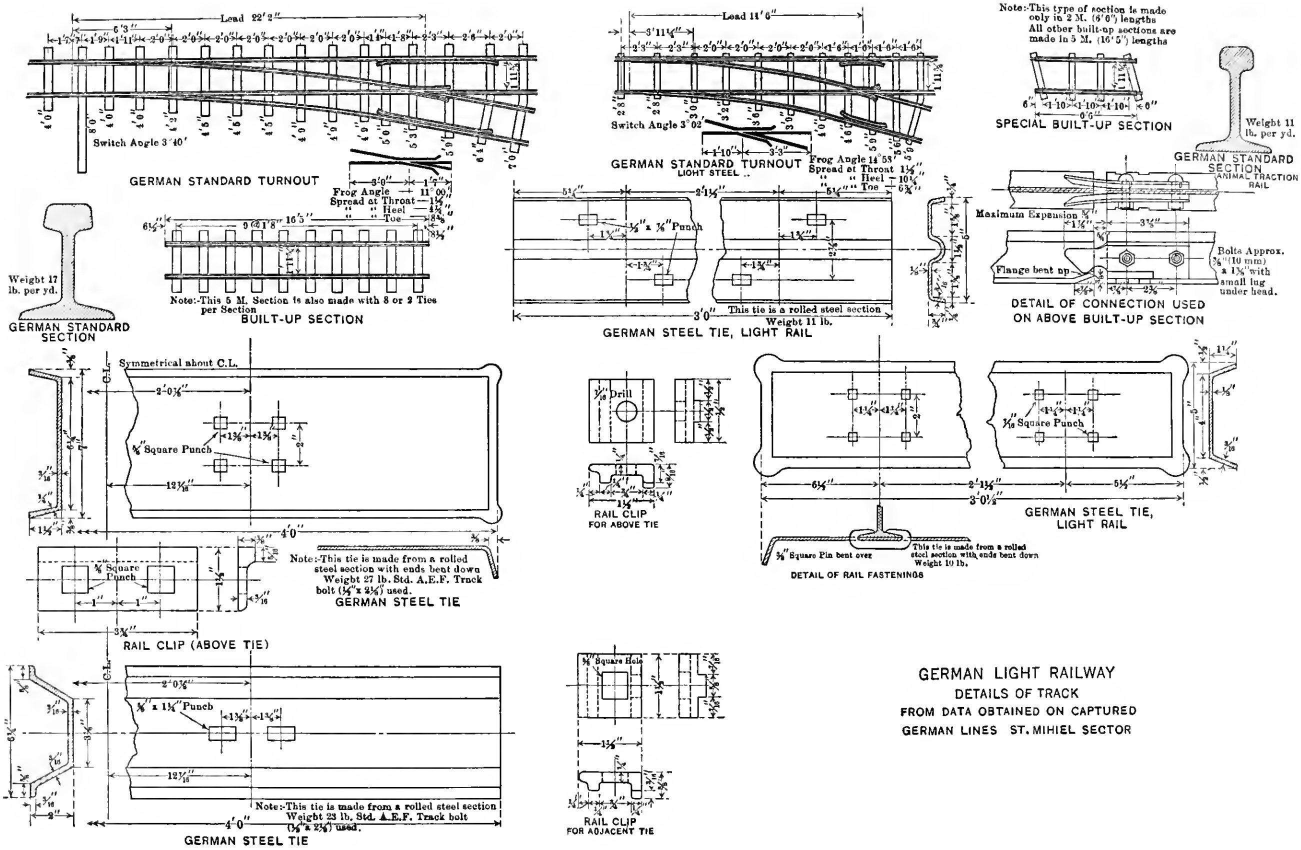


LIGHT RAILWAYS
RAILHEAD AT SORCY
MEUSE



LOCATION OF
LIGHT RAILWAY
ABAINVILLE SHOPS
TO
SORCY RAILHEAD



GERMAN LIGHT RAILWAY
DETAILS OF TRACK
FROM DATA OBTAINED ON CAPTURED
GERMAN LINES ST. MIHIEL SECTOR

The speed with which tracks could be constructed by the different Allied armies was practically the same. In September, 1917, the British stated that the construction of 1 mile of track, including ballasting, required 2 100 man days of labor. The "French Manual of Light Railway", issued in April, 1918, states that their average had been ⅜ m. per man per day, which is equivalent to 2 146 man days.

Most Important American Line.

On the American front, the most important line, and the best constructed, was the connection between the central shops and storage yards at Abainville and the front line system at the Sorcy rail-head (see Plate II), a line 18½ miles long, on which the average speed of construction was 2 640 man days per mile. As this line, together with the shops and yards at Abainville, and the Sorcy rail-head, was the most important light railway job constructed by the American forces, and as several interesting engineering problems were presented in their construction, they will be described in some detail.

When the American troops first went into the line in the St. Mihiel Sector, the base from which their supplies were drawn was Toul. As the French had troops in the line immediately east of the Americans, and were also using Toul as a base, it became congested, and the French suggested that the Americans build an independent rail-head at Sorcy, 11 miles west of Toul, which was done. This rail-head had the necessary facilities for transferring material from broad gauge to narrow gauge, and from car to motor truck; also warehouses, platforms, etc. It was regarded as very convenient, and represents a typical lay-out (see Plate II).

From this rail-head at Sorcy, the American forces built a 60-cm. line to Cornieville (5 miles), where connection was made with the French system of light railways radiating from Toul. They also took over the operation of the French lines on the west half of the sector, St. Mihiel-Pont-a-Mousson.

The location for the central shops and storage yards of the "Light Railway" system was a matter for careful deliberation. Many sites were examined and reported on, the objections to most of them having been that they were either too close to the front, too far to the rear, too far to the left, or too far to the right. It was necessary to find a location that would afford ample space for a large yard, with standard-

gauge rail connection, and preferably canal connection as well. It was desirable also to have a location, at least, 30 km. back of the front line, as prisoners of war could be used if they were kept back that far; however, the Americans did all their work with their own troops.

Abainville, 2 km. north of Gondrecourt, was recommended by the writer, in March, 1918, as a suitable location for shops and yards, which recommendation was approved. Subsequent events proved it to be a most desirable location, as it was directly behind the St. Mihiel and Argonne fronts, on which the greater part of the American operations were conducted. Abainville was 35 km. back of the line, and was not within the area usually bombed by the Germans.

The shops were designed for the repair of "Light Railway" locomotives and gasoline tractors and for the assembly and repair of freight equipment; and the yards were designed for the storage of track and bridge material. The whole plant covered an area of 116 acres. The track arrangement was such that material coming up from the ports on standard gauge was unloaded in the storage yard and subsequently taken to the front, as required, on the "Light Railways".

The shop buildings consisted of the Austin type of steel building, and were erected by the American troops under the direction of a superintendent of the Austin Company, who had been sent over for that purpose. The buildings were of steel framework, boarded in with lumber obtained in France. The roof was boards covered with prepared roofing. The buildings were generally 40 ft. wide, 200 ft. long, and included an erecting shop, machine shop, gas-engine and auto repair shop, planing mill, two storehouses, car shop, foundry, blacksmith shop, power-house, and oil house.

Skillful Location Required.

In the construction of the line leading from these shops to the Sorcy rail-head, it was stipulated by the French authorities, that there should be no grade crossings of the standard-gauge railways and no interference with navigation on the canals. These requirements necessitated skillful location.

The line was projected on the French standard contour maps 1 to 20 000, a study of which showed the feasibility of a line with grades not to exceed 3 per cent. An examination of the route showed that the necessary crossings of standard-gauge tracks could be made under

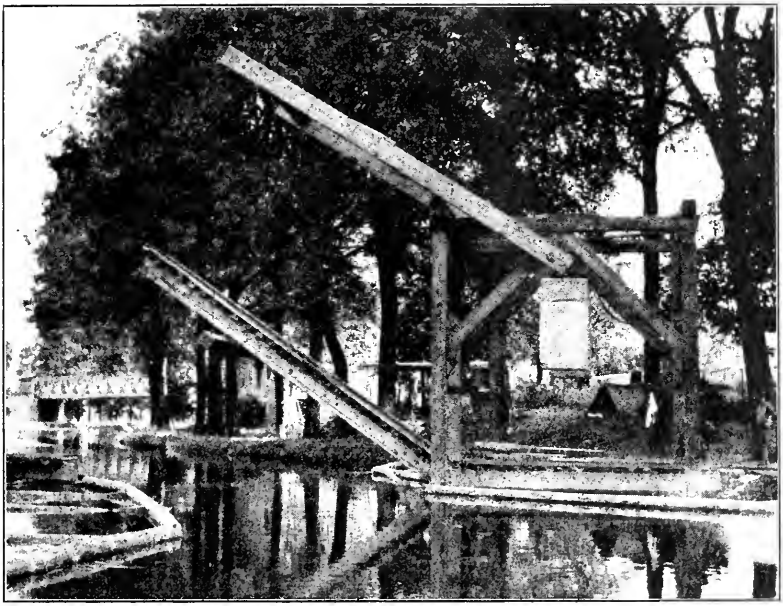


FIG. 2.—LIFT BRIDGE OVER CANAL AT VOID (MEUSE).

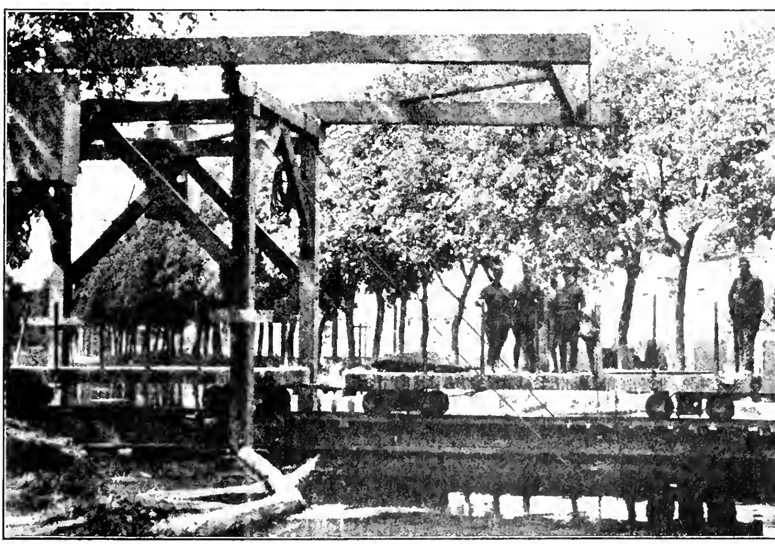


FIG. 3.—LIFT BRIDGE OVER CANAL AT VOID (MEUSE).

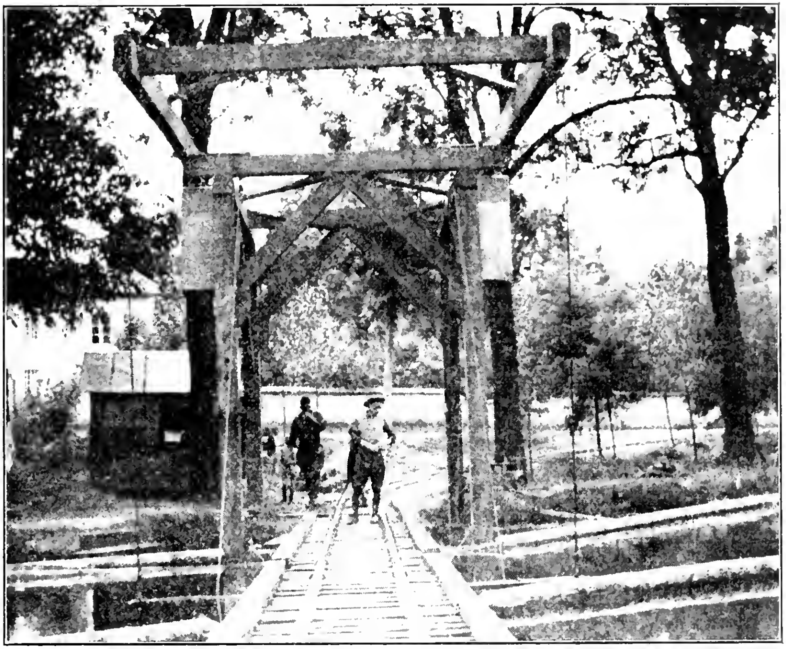


FIG. 4.—LIFT BRIDGE OVER CANAL AT VOID (MEUSE).

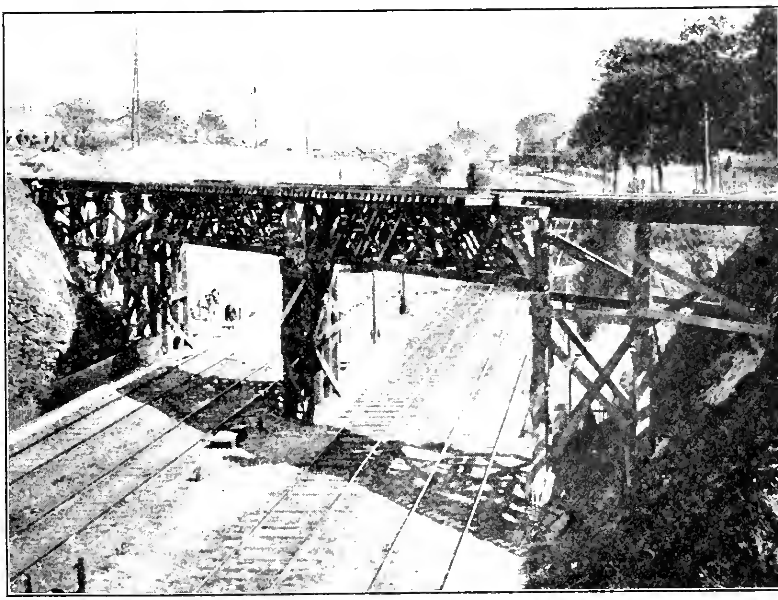


FIG. 5.—BRIDGE OVER CHEMIN DE FER DE L'EST, AT SORCY (MEUSE).

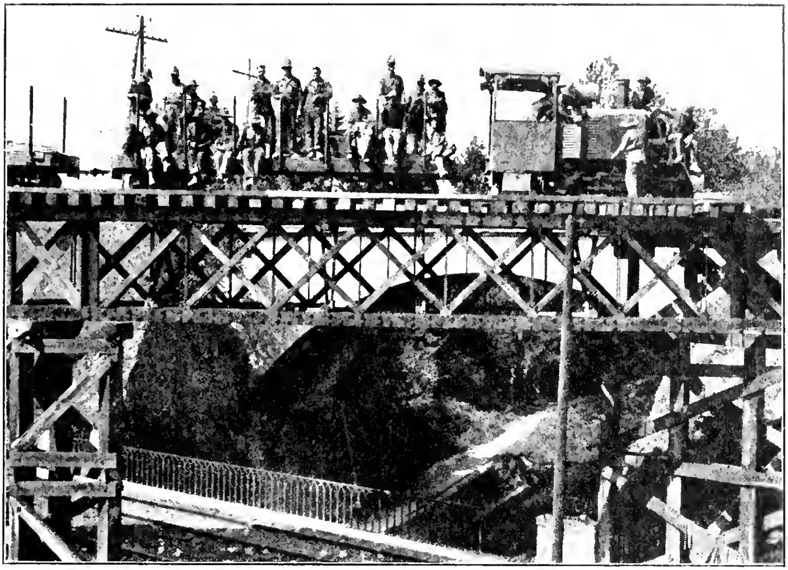


Fig. 6.—Bridge Over Chemin de Fer de l'Est, at Sorcy (Meuse).

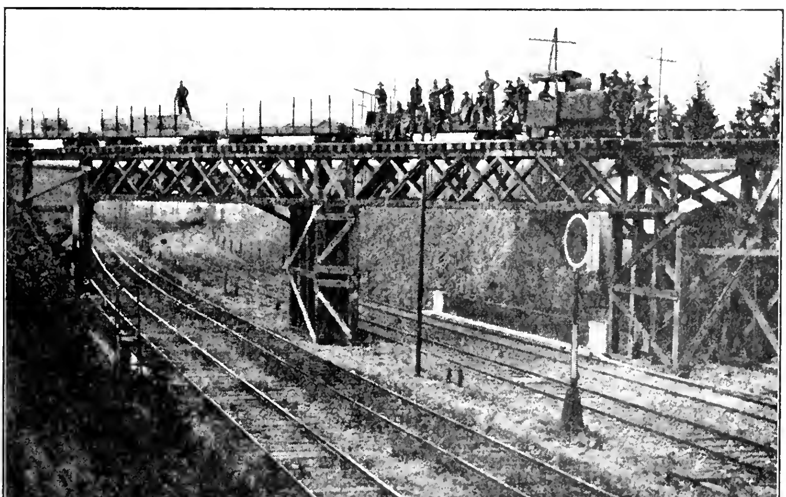


Fig. 7.—Bridge Over Chemin de Fer de l'Est, at Sorcy (Meuse).

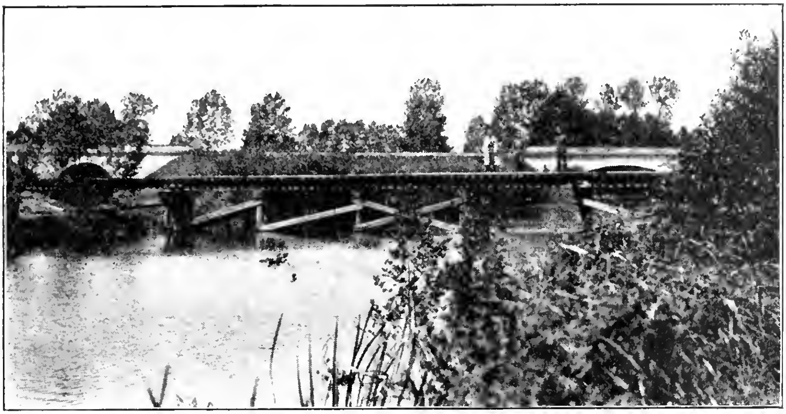


Fig. 8.—Bridge Over Meuse River Near Void.

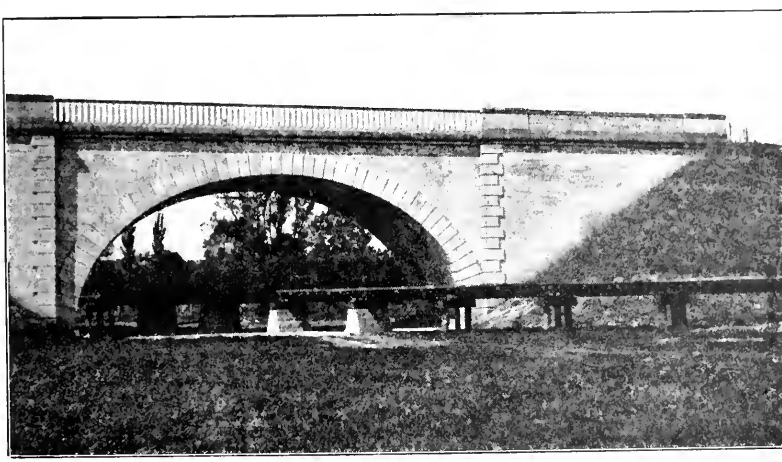
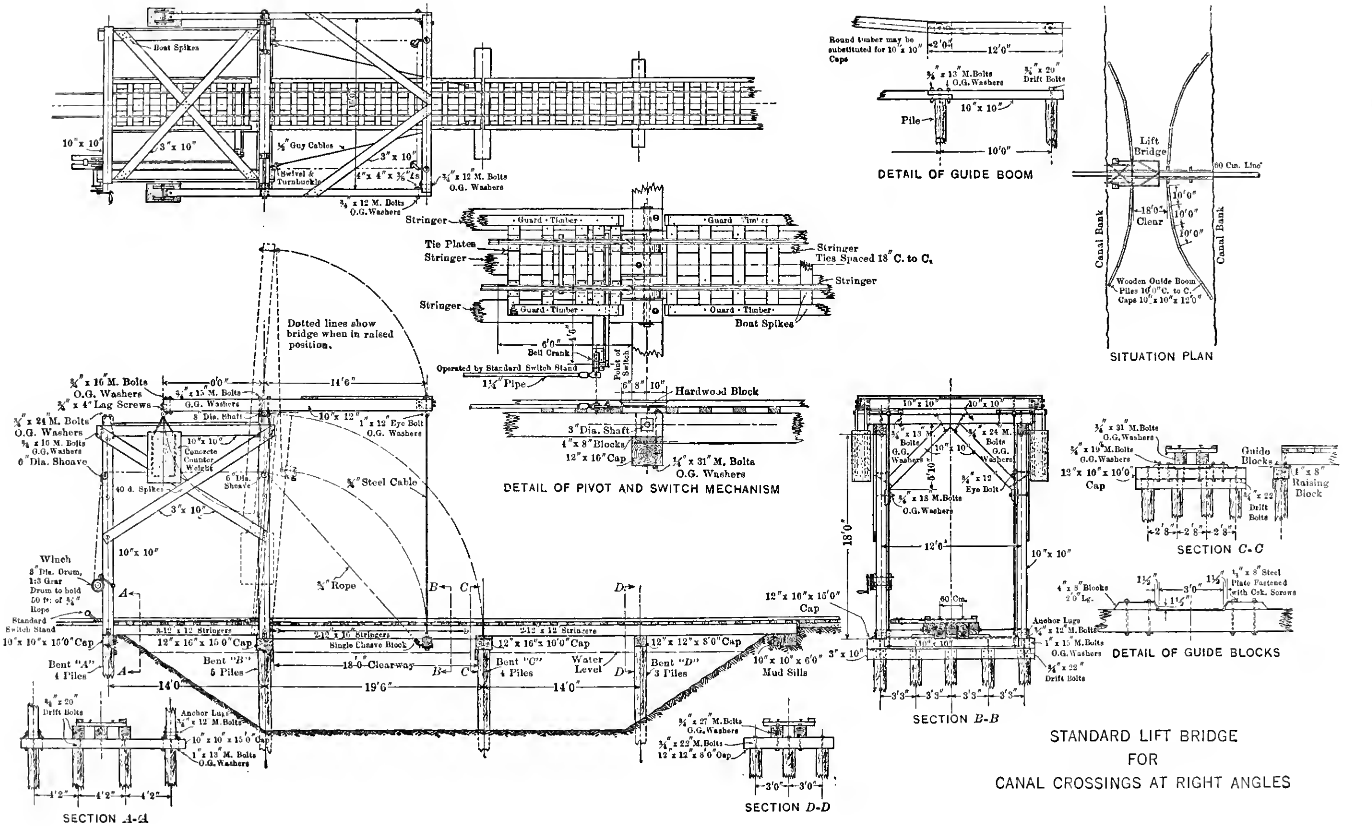


Fig. 9.—Crossing Under Chemin de Fer de l'Est near Void.



STANDARD LIFT BRIDGE
FOR
CANAL CROSSINGS AT RIGHT ANGLES

the main line viaducts or through large culvert openings. These points were selected as the governing conditions of the location, and the line was run accordingly. It was found that the French maps were extremely accurate—the summit elevations checked out exactly—the grade line and work was just what was expected.

It was necessary to cross the Marne-Rhine Canal at Void. The limited room for the 60-cm. line in this town necessitated crossing the canal at an angle of 68°, requiring a span of about 28 ft. to preserve the standard 6-m. width of waterway at right angles. Fortunately, the American engineers had some bridge stringers 8 by 16 by 28 ft., which had been sent over from the United States. The writer designed a counterweighted lift bridge (see Figs. 2, 3, and 4) with this material, which could be operated by one man. This proved so successful, that a standard plan was made for lift bridges, and as it was expected that most of the canal crossings could be constructed at right angles, a complete bridge was built and kept in reserve, the details for which are shown in Plate IV.

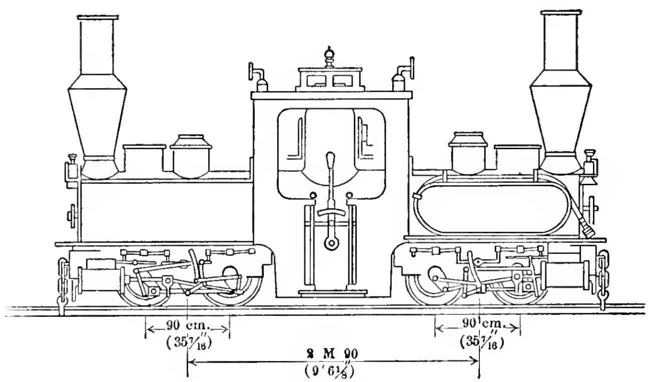
At Sorcy, it was necessary to cross the main line of the Chemin de Fer de l'Est, and as it was near the junction of the line from Gondrecourt with the main line, four main line tracks were crossed (see Figs. 5, 6, and 7). The railway at this place crossed over the canal, and the 60-cm. line was located to cross the standard-gauge tracks and canal at the same place. Fortunately, this crossing occurred in a cut, so that the line could be carried across with the minimum of bridging.

No girders or spans were available for this crossing, and it was necessary to design and build a bridge with the available material. It was found that two deck Howe trusses, with a few bents of trestle approach, would fit the conditions, give the necessary clearances, and would be the most practicable type of structure. These trusses were built of 5 by 10-in. road plank, and each truss weighed about 4½ tons. There was a locomotive crane working in the yard, which could lift 5 tons, so that after the bents were erected, the trusses were picked up by the crane and set in place in a few minutes. The whole bridge was framed and erected in five days, with no interference or delay to the traffic on the standard-gauge lines.

The Meuse River was also crossed by this line. At the place of crossing the stream was 125 ft. wide, with 14 ft. of water, and had very little current. Pile trestles were used in this case, as shown by Fig. 8.

The main line of the Chemin de Fer de l'Est was crossed in the Meuse River bottom through an overflow relief opening. A view of this structure is shown in Fig. 9, which is a good example of the splendid, beautiful, masonry structures which one sees everywhere on the French railways.

The types of engines and cars used on these railways are shown herewith. The Baldwin engine would handle 60 tons of freight up a 3% grade. The steam locomotives were not used up to the point where their smoke and steam would betray their presence to the enemy; some little distance back from the front lines they would be cut off, and the cars were handled to the extreme front by gas engine. The operating rules were extremely simple, and dispatching was done by telephone.

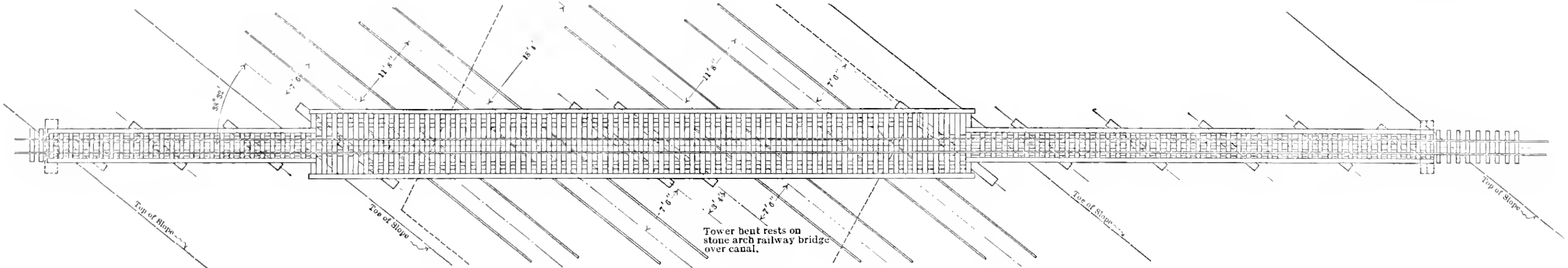


FRENCH DOUBLE END STEAM LOCOMOTIVE
FOR LIGHT RAILWAY
MODEL 1888

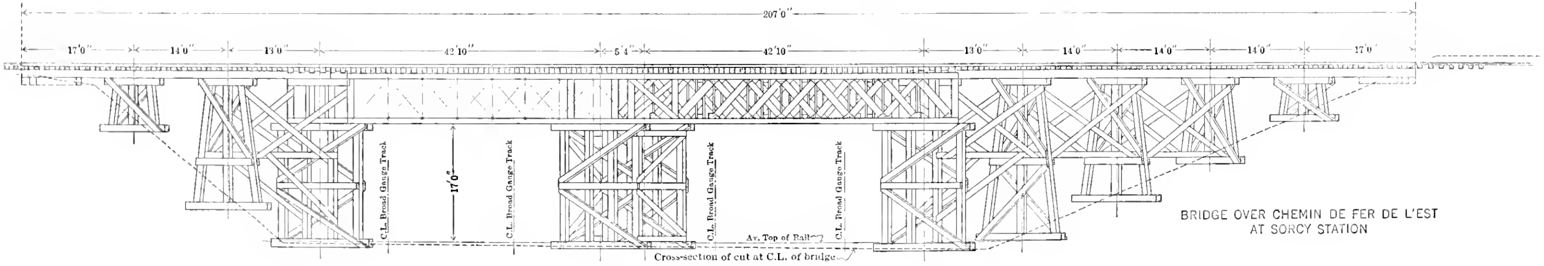
TABLE 1—A. E. F. LIGHT RAILWAY FREIGHT CARS.

	Box, covered.	Box. open top.	Gondola.	Flat.	Dump V shape.	Tank.
Capacity	600 cu. ft. 22 000 lb.	....	210 cu. ft. 22 000 lb.	22 000 lb.	27 cu. ft.	2 000 gal.
Weight..............	10 900 lb.	....	9 000 lb.	8 000 lb.	1 050 lb.	12 200 lb.
Length, inside.......	19 ft. 10 in.	....	19 ft. 8¾ in.	22 ft. 1 in.	5 ft. 8 in.	19 ft. 5½ in.
Width, inside........	5 ft. 5 in.	....	5 ft. 3 in.	5 ft. 3 in.	4 ft. 8 in.	5 ft. ½ in.
Height, inside.......	5 ft. 8 in.	....	2 ft.	5 ft. 7 in.	....	....
Length, over coupler	24 ft. 1¼ in.	....	24 ft. 1¼ in.	24 ft. 1¼ in.	6 ft. 9 in.	24 ft. 1¼ in.
Width, over all......	6 ft. 6¼ in.	....	5 ft. 7 in.	5 ft. 7 in.	4 ft. 8⅝ in.	5 ft. 7 in.
Height, over all from rail........	8 ft. 4¾ in.	....	4 ft. 4⅝ in.	....	4 ft. 5 in.	....
Height, to floor.....	2 ft. 4¼ in.	....	2 ft. 4¼ in.	2 ft. 4¼ in.	....	2 ft. 4¼ in.
Height of coupler...	17 in.	....	17 in.	17 in.	17 in.	17 in.
Wheel base, truck..	3 ft.	....	3 ft.	3 ft.	24 in.	3 ft.
Distance, C. to G. trucks...........	15 ft.	....	15 ft.	15 ft.	....	15 ft.
Diameter of wheels.	15¾ in.	....	15¾ in.	15¾ in.	14 in.	15¾ in.

PLATE V.
PAPERS, AM. SOC. C. E.
JANUARY, 1920.
JONAH ON
"LIGHT RAILWAYS" OF THE BATTLE FRONT.



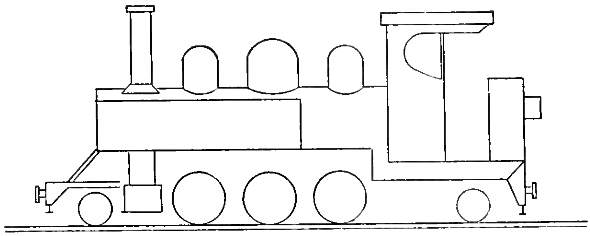
PLAN



BRIDGE OVER CHEMIN DE FER DE L'EST
AT SORCY STATION

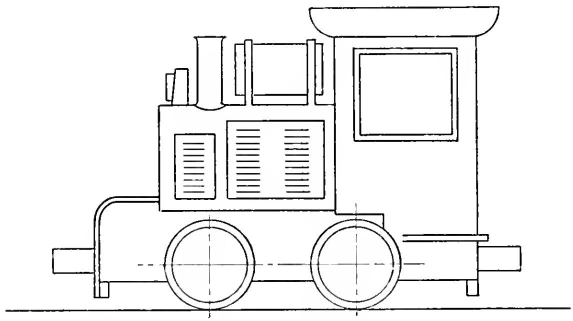
SIDE ELEVATION

A. E. F. LIGHT RAILWAY STEAM LOCOMOTIVE.



Type	2-6-2
Gauge	$23\frac{5}{8}$ in. (60 cm.)
Working pressure	178 lb. sq. in.
Curve, minimum radius	65 ft. $7\frac{3}{8}$ in. (20 m.)
Driving wheel base	5 ft. 10 in.
Total wheel base	15 ft. 7 in.
Length between couplers	21 ft. 7 in.
Height of coupler, rail to center line	$16\frac{1}{2}$ in.
Width, maximum	6 ft. 5 in.
Height, maximum above rail	9 ft. 3 in.
Weight on drive wheels	23 500 lb.
Weight on front truck	5 000 lb.
Weight on rear truck	5 500 lb.
Total	34 500 lb.
Tractive effort	6 225 lb.
Ratio of adhesion	3.7
Coal capacity	1 700 lb.
Water capacity	486 gal.

A. E. F. Light Railway Gas Locomotive.



Type	4-wheeled, 4-cylinder, 4-cycle, vertical, water-cooled
Gauge	$23\frac{5}{8}$ in. (60 cm.)
Wheel base	4 ft. 0 in.
Horse-power	50
Fuel capacity	30 gal.
Length over all	13 ft. 0 in.
Width over all	5 ft. 2 in.
Height over all	8 ft. 5 in.
Height of coupler, rail to center line	16 in.
Weight, total	14 000 lb.
Transmission	2 sets of speed change gears
Draw bar pull (Level track)	Low gear, 3 000 lb. High gear, 1 500 lb.
Speed	Low gear, 4 m. p. h.; high gear, 8 m. p. h.
Brakes	Hand brakes to all drivers

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE EAST CANYON CREEK DAM

Discussion*

By A. F. Parker, M. Am. Soc. C. E.†

A. F. Parker,‡ M. Am. Soc. C. E. (by letter).||—According to reports arch dams have been built with unit stresses varying from 61 tons per sq. ft., down to 10 tons per sq. ft. They have also been built of poor materials and have departed considerably from true arch form; but, notwithstanding, there is no record of failure of an arch under water pressure. No one knows how great a loading from water pressure is required to break an arch, and, therefore, it is not known where the danger point lies or how near to it designs come. Mr. Parker.

All calculations to ascertain the strength of arch dams are based on theory and individual assumptions which vary according to the ideas of the designer. In other structures, the breaking point is often known and thus a basis is established for intelligently applying a factor of safety, but, in all cases, facts, demonstrated by actual examples under use, finally govern. Why not frankly admit that there is no accurate knowledge of stresses in hydrostatic arches and adopt the simple formula for compressive strength in cylinders? Authorities do not agree as to the action of any stress except compressive. It will be found that, for arches not exceeding a compressive stress of, say, 25 tons per sq. ft., none of the requirements imposed by the use of numerous complicated formulas, all based on assumptions, calls for any increase of dimensions set by the simple formula.

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* Discussion of the paper by A. F. Parker, M. Am. Soc. C. E., continued from September, 1919, *Proceedings*.

† Author's closure.

‡ Ogden, Utah.

|| Received by the Secretary, December 29th, 1919.

Mr. Parker.

Why not recognize precedents established by examples and adopt a factor of safety based on the actual compressive strength of the concrete used? This would be more rational than to rely on calculations based on unknown conditions which must be guessed at. From the published discussions of the subject, one can only conclude that designers have been proportioning arch dams by individual judgments; or, that is what it amounts to in the end.

There is only one rational way to ascertain, in advance of construction, the strength of concrete, and that is to fabricate actual concrete such as it is intended to use, mould it into test specimens of not less than 10 in. in diameter, so that the specimen is as truly like the concrete that will be produced on the job as it is possible to have it. Such test blocks broken in a compression machine of not less than 400 000 lb. capacity, at 30-day intervals until 6 months have elapsed, will give a basis on which to use a factor of safety.

The writer is fully convinced that the East Canyon Creek Dam is over conservative with its unit stress of 12.5 tons per sq. ft. A procedure like the one stated above would have resulted in a unit stress of, at least, 25 tons. It is the writer's opinion that such a stress could have been safely used in designing this dam, with a corresponding saving in concrete.

So long as the rock on which the arch is built is as good as the concrete composing the arch, there is nothing to fear from water pressure but failure under compressive stress. There is nothing to fear in an arch from uplift or pressure caused by water finding access to joints, just as long as concrete weighs more than water. The hydrostatic pressure is completely balanced on and resisted by the arch; this produces a definite compressive stress in the concrete of the arch.

This definite and balanced loading is wherein the arch dam differs from other arches and structures. There is no varying or live load; so it must be that calculations have a safer basis than in most cases. Ice thrust may be guarded against by vertical reinforcement, simply to distribute the ice pressure over more of the arch, above and below the ice.

The foregoing is prompted by reading Mr. Godfrey's discussion* and will suffice to indicate the writer's opinion of it.

Mr. Fortier's discussion† brings out some very interesting points. The development of the idea for building a dam by successive stages is well done; it must be remembered that it is in its adaptability to such practice that the arch differs from other forms of dams. The idea of using tangent gravity structures at the ends of the arch for it to abut

* *Proceedings*, Am. Soc. C. E., May, 1919, p. 335.

† *Proceedings*, Am. Soc. C. E., August, 1919, p. 543.

upon where the natural contour of the canyon does not admit of using a full arch or, in other words, when the site does not admit of the use of an entire arch, to form an artificial canyon of the proper profile for an arch by means of these gravity sectioned tangent ends, is well illustrated in Mr. Bellamy's discussion. It is to be regretted that Mr. Fortier did not discuss the technical features of the dam. Mr. Parker.

Mr. Wiley's discussion* gives a very interesting and instructive example of the superior qualities of arch dams. It is safe to say that in no other form than an arch can materials be made to withstand such abuse as is described in the case of the Crowley Creek Dam. It is notable that the unit stress reaches a maximum of 440 lb. per sq. in., or more than 31 tons per sq. ft. In spite of its imperfections and heavy unit stress, it withstood severe conditions of ice and floods. It adds important and convincing testimony to the increasing number of examples of abuse of workmanship and heavy loading that arch dams can stand up under.

In Mr. Wiley's comments on shaping the abutments to radial lines he states a sound principle, but, in this case, the work was carried out in a different way because of peculiar conditions that may not occur again. The design was made contemplating radial lines for all such joints and contact points.

It was an oversight that the cost of cement was not included in the cost of concrete. The figures were made up from the contractor's final estimate which did not include the cement and so it was overlooked. The prices are all contract prices, and the actual cost to the contractor of the whole or any item is not known.

Mr. Bellamy's discussion† shows an excellent example of using an arch for a dam in a canyon too wide to be filled entirely by the arch. It is an application of the principle so well stated by Mr. Fortier and shows, at a glance, the economy of cutting out the center and most costly portion of a gravity dam and substituting the cheaper arch form, cheaper because of less material in the structure and much cheaper by reason of reduced excavation for the foundation. Calculating by the simple formula a section 100 ft. below the top, it is found that the unit stress from compression is more than 22 tons per sq. ft. Also, the concrete materials are said to be poor; but still the dam does not fail. It is another argument for the idea that engineers are inclined to be too conservative in building arch dams.

Mr. Bellamy's whole discussion points to the wisdom, in designing an arch dam, of following the method of testing materials previously pointed out. Tensile tests of briquettes of cement and standard sand

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* *Proceedings*, Am. Soc. C. E., August, 1919, p. 549.

† *Proceedings*, Am. Soc. C. E., September, 1919, p. 625.

Mr. Parker. are only tests of the cement to show how it will behave with sand in making a mortar. The same kind of test of cement mortar made with other than standard testing sand is only a mortar test, and tensile at that. None of such tests is more than a rough, very rough, indication of what may be expected for compressive strength. The only true test is one made on large test blocks of the actual sizes and proportions of the aggregates used in the concrete.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

SEWAGE AND WASTES DISPOSAL FOR THE UNITED STATES ARMY

Discussion*

By Messrs. J. F. Brown and Lynn E. Perry.

J. F. Brown,† Assoc. M. Am. Soc. C. E. (by letter).‡—The type of sewage treatment plant adopted by the Construction Division of the Army for installation in the Army camps and industrial plants during the war, is so radically different from that ordinarily encountered in municipal practice that some discussion of the principles underlying its design and operation seems to be warranted. Mr. Brown.

Maj. Doten has described in a general way the outstanding features of the standard sewage tank and the sections of the tank shown on Plate IV of his paper give the details of the structure. It may be said that some of the details, particularly the rectangular sumps at the bottoms of the hoppers, are not typical of the standard design and are not found in any of the tanks serving the larger camps. The sloping baffle at the inlet end of the tank is another feature not typical of the earlier designs, having been adopted as a standard detail only after the recognition, on the part of the designing engineers of the Construction Division, of the presence of such large quantities of grease in the sewage, and the necessity of preventing the entrance of this material into the tanks. The original plans included vertical baffles at both the inlet and outlet ends, all compartments in any one tank were of equal dimensions, the slope of the floors of the hoppers was much flatter than that shown in Plate IV, and there were no sumps under the lower ends of the sludge eduction columns.

* Discussion of the paper by Leonard S. Doten, M. Am. Soc. C. E., continued from October-November-December, 1919, *Proceedings*.

† Kansas City, Mo.

‡ Received by the Secretary, December 22d, 1919.

Mr. Brown. In operation, sewage enters the tank at the water level and is immediately deflected downward by the inclined baffle. Particles of grease, and débris, such as match sticks, fruit skins, etc., which float on the incoming stream of sewage, are caught in front of the sloping baffle and may be skimmed off at frequent intervals, thus preventing the entrance of such materials into the tanks. The downward flowing sewage passes under the baffle and into the first compartment where, owing to the increase in area of the flow section and consequent decrease in the velocity of flow, the heavier particles of solid material are deposited. The lighter particles are carried on in the current under the vertical baffle at the outlet end of the first compartment, over the partition or weir wall and into the second compartment, where further sedimentation obtains. The same process is repeated in the third and fourth compartments, the effluent collected over the outlet weir into the effluent trough being practically free from suspended or settleable solids. It is the repetition of the sedimentation process, carried out in four separate stages, which accomplishes such a remarkable clarification of the sewage.

Many data are now available showing the results of extended tests of tanks in several of the larger camps, indicating the high efficiency of this type as a sedimentation tank, and it is hoped that Maj. Doten will publish them before his work in the Construction Division is concluded.

Coincident with the multi-stage sedimentation process is the multi-stage sludge digestion process which, unless the liquor in the tank has been "soured" by the products of decomposition of grease, has proceeded to a remarkable extent in many of the Construction Division sewage tanks. With the decomposition of organic solids and the consequent evolution of gas, particles of organic material which have been deposited in the inlet compartment are comminuted or split up by the pressure of the gas generated within them. The gas thus generated rises into the liquor above the sludge, carrying with it partly digested particles of sludge. The finer gas-borne particles rising into the liquor are caught in the current of sewage and carried forward, either to be re-deposited at a point nearer the outlet end of the compartment than that from which they were lifted from the sludge, or carried over the partition wall into the second compartment. The larger gas-borne particles ascend into the liquor above the sludge and continue to rise until the attached charge of gas is liberated into the air, when they settle again to the sludge layer. This process of comminution and carrying forward of the partly digested solids continuing until the larger solids have been broken up into particles sufficiently small to be carried by the current over the partition wall into the second compartment.

In the second and in each of the succeeding compartments the process of comminution, gas generation, and carrying forward of the more finely divided particles continues, the final effluent from the tank being practically free from settleable solids, and the sludge accumulating in the final compartment being well digested and easily dried on sludge filters. Mr. Brown.

The inclined baffle at the outlet end of the fourth compartment is designed to deflect backward toward the center of the compartment the gas-borne particles that rise from the sludge deposits near the end of the chamber, thus preventing their passing out with the effluent, even at times when the digestive action in this chamber is progressing vigorously.

The most striking points of difference between the municipal sedimentation or digestion tanks and the standard Construction Division tank include improved arrangements for sludge withdrawal, a separate sludge eduction pipe being provided in each of the compartments, so that sludge can be withdrawn from any compartment; by means of the sludge pipes the accumulation of sludge in any compartment can be transferred into any other compartment for further digestion; and by means of the water pipe connection into the sludge line, the sludge accumulation in any compartment can be thoroughly agitated. These features facilitate the operation of the tank, the most important feature from this standpoint being the arrangement of piping in such a way that sludge can be transferred from one chamber to another. Although the normal processes of comminution and carrying forward of sludge particles tend to effect a restoration of sludge-storing capacity in the inlet compartments of the tank, it sometimes happens that, in periods of excessive sewage flow, or at times when the digestive action in the inlet compartment is weak, the accumulation of sludge in this chamber becomes excessive, and it is necessary to relieve the condition by transferring the sludge to one or more of the other compartments.

Important differences exist between the secondary treatment units and the auxiliary structures of the Army sewage plants and those of a similar type found in municipal sewage plants. The dosing tanks for all plants constructed in 1918 were designed for a holding capacity equal to the discharging capacity of the filter nozzles for 1 min., thus providing a maximum length of dosing period not exceeding $1\frac{1}{2}$ min., at maximum rate of sewage flow. Several of the dosing tanks constructed in 1917 were altered during 1918, their capacity being reduced to this basis, a remarkable improvement in the filter effluent following each such alteration. Sprinkling filters were designed during 1918 with an effective depth of 5 ft., and with the exception of a few small ones treating sewage from Army hospitals, no filters were constructed of a depth greater than 6 ft. The areas of the filters were designed on the basis of treating the sewage from 30 000 persons per acre of

Mr. Brown. filter, which is approximately equivalent to a sewage flow per acre per day of 2 000 000 gal.

The sludge filters, or drying beds, were much shallower than are most municipal structures of this type, the total average depth of the filtering material being 15 in., made up of 12 in. of crushed stone and 3 in. of sand. The filters for sludge drying were not provided with concrete floors, nor were the inner slopes of the embankments paved. The under-drains consisted of vitrified sewer pipe laid in the depressions of the subgrade, each under-drain serving an area approximately 10 ft. in width. In designing sludge filters, an area of $\frac{1}{3}$ sq. ft. per capita of population served was allowed. This was found to be ample; in fact, in one case, the sludge from the sewage tanks was dried with no difficulty on a very much less area per capita than that stated.

Secondary settling tanks were provided in a very small number of plants. These were designed with a holding capacity of about $\frac{1}{2}$ hour's flow of sewage. Where disinfection of sewage effluent by liquid chlorine was carried out, the secondary settling tank was provided with a gas-tight concrete slab cover, water-sealed traps on both inlet and effluent lines, and in this tank the chlorine was applied to the sewage.

From January 1st, 1918, until March, 1919, the writer visited in his official capacity nearly all the sewage treatment plants installed by the Construction Division, as well as many plants installed by other Government agencies, and several municipal plants. Gross as has been the neglect of municipal sewage treatment plants—and every sanitary engineer knows that the operation of most municipal plants has been characterized by wanton neglect—the Army sewage plants fared even worse. During the latter part of 1917 and the early part of 1918, no definite military organization had yet been formed which would have charge of, and direct the operation of, the various camp utilities such as the water supply and distribution systems, the sewerage and sewage treatment plants, etc. Not only was there no skilled attention given to these plants, but even the most obvious needs were neglected. Sewer manholes were used as receptacles for cast-off clothing, kitchen garbage, and all sorts of débris; screen chambers, where these had been installed, were allowed to clog and fill to overflowing; sewage tanks were permitted to fill with accumulations of sludge and scum, and no attempt was made to keep the nozzles on the sprinkling filters clear. Even the most casual inspection would have shown the serious need of immediate attention. The one or two plants, notably the one at Camp Merritt, N. J., which were operated by attendants who possessed some experience in the working of sewage plants, were able to handle the suddenly varying and often excessive loads which came on them without any serious difficulty.

Early in the summer of 1918, with the organization of the Maintenance and Repair Branch of the Construction Division, many sanitary

engineers were taken into this branch of the service, and placed in charge of the operation of the camp utilities. This arrangement brought about a marked improvement in the methods of operation of sewage plants, and in the months immediately following its adoption many of these plants were quickly brought into a satisfactory operating condition. Mr. Brown.

The writer has read with interest the discussion of Maj. Doten's paper which have been published in recent numbers of *Proceedings*. Some of the opinions therein stated are apparently based on observations made during the spring and early summer of 1918, when nearly all Army sewage plants were clogged and filled with grease, and in many cases all digestive action in the tanks had ceased, due to the acidifying of the liquid resulting from decomposition of grease. Up to this time, as previously mentioned, no effort had been made on the part of the local camp authorities to protect the tanks from the excessive quantity of grease discharged into the sewers from the camp kitchens, and the enormous amounts of débris and garbage which were wantonly deposited in the sewer lines. Under the better conditions resulting from the installation of efficient grease traps and coarse bar screens, and intelligent operation, the conditions have almost completely disappeared.

The writer questions the statement that efficient tank treatment may be accomplished by the so-called two-story tank, especially if such a tank were to be used for the treatment of fresh, concentrated, grease-laden camp sewage. Reports of the conditions of Imhoff tanks in several of the Army Aviation Fields covering the first half of 1918 do not indicate that any considerable success was attained in their operation. In fact, it was found that these tanks were absolutely inefficient both as sedimentation tanks and as digestion tanks.

While admitting that it is the consensus of opinion that the effluent from a septic tank cannot be treated by processes of bacterial oxidation —such as filtration through trickling filters—as advantageously as one which is not effected by the products of decomposition of sewage solids, the writer believes that the arguments advanced in support of this opinion are academic in their nature, and are not borne out by facts. He is of the opinion that the results of the series of chemical analyses made by the Bureau of Chemistry of the Department of Agriculture on both tank and filter effluents at the Fort Myer plant, which were quoted by Maj. Doten, indicate the fallacy of this opinion. It would appear, by logical deductions from the results of these tests, that the processes taking place in the Fort Myer tank rendered the effluent especially susceptible to treatment on a trickling filter. Maj. Doten has apparently reached a similar conclusion regarding the success attending the treatment of the effluent from a tank of the Construction Division type on a trickling filter. Additional evidence supporting this conclu-

Mr. Brown. sion can undoubtedly be collected by a study of existing records of chemical analyses of such effluents, and it is hoped that Maj. Doten will present at least a summary of the data found in these records before the discussion of his paper is concluded.

Mr. Perry. LYNN E. PERRY,* Assoc. M. Am. Soc. C. E. (by letter).†—The first tank built by the Construction Division of the Quartermaster Corps which the writer had the good fortune to inspect was at Fort Myer, Va. This was in May and June, 1917. When his attention was first drawn to it, it was under construction, but was rapidly completed and placed in operation. The writer's opinion was that it would act as a clarification tank rather than as a sludge digestion tank. Its remarkable efficiency as a settling tank impressed him forcibly; especially as he remembers very distinctly, that the effluent was turned on the sprinkling filters when they were little more than one-third filled with stone. At that time, the effluent from the filters flowed through a very small ditch which showed no evidence of carrying an unstable flow during his stay at Fort Myer.

In discussing the design of this tank with H. C. McRae, Assoc. M. Am. Soc. C. E., at that time, the writer did not believe that the advantage of the pyramidal bottom was commensurate with its cost; it was not sufficiently steep to force the sludge down, although it was too steep for men to stand on while cleaning the tank.

After reading Maj. Doten's paper and learning that an attempt has been made to obtain efficient digestion in these tanks, the idea has occurred to the writer that probably better results might have been obtained if the tanks had been constructed so that the flow could be reversed, horizontally. This has been done in some recent designs of Imhoff tanks and although the writer has not observed any considerable improvement, a logical attempt, at least, has been made to help the operator over his difficulties.

The writer cannot refrain from expressing his commendation to Maj. Doten for not adopting some form of the Imhoff tank as a standard of the Construction Division. Due to certain propaganda, almost all the laity and a large percentage of engineers regard the Imhoff tank as a panacea for all sewage ills. Indeed, it was stated by at least one sanitary engineer, in an address to a convention of Sewage Plant Superintendents, that in the design of the Imhoff tank a totally satisfactory method of treating sewage had been obtained. Those who have had to do with the operation of Imhoff tanks, mildly speaking, are skeptical of such an assertion.

Several series of investigations have been conducted in an endeavor to learn the cause of "foaming", or what measures will stop or prevent "foaming". These have been almost fruitless. One investigation seemed to indicate that when a tank was placed in operation

* Easton, Pa.

† Received by the Secretary, January 2d, 1920.

in the autumn or winter the low temperature inhibited the growth of liquefying bacteria; the sludge became acid and resulted in "foaming". On the other hand plants placed in operation during the spring or early summer digested their sludge well before cold weather; the sludge was highly alkaline, sufficiently so to keep the digestive process going until warm weather again arrived. The number of plants considered in this investigation, however, was small, and mention of it is made merely to indicate how thoroughly the writer has gone into the operation of Imhoff tanks in an endeavor to secure uniformly satisfactory results. Mr. Perry.

There has never been sufficient co-operation between the designers and operators of sewage plants to obtain the best results. It would seem that the Army proved no exception. Having been interested from both angles, the writer will not comment further.

Early in the war, the writer was assigned to one of the Aviation Fields, where the garbage problem was handled by the duplicate can system. No garbage cans were ever taken into the kitchen; they were kept on a screen-covered fly-proof platform some distance from the kitchen door. The wagons came alongside the platform, loaded the full cans without removing the covers, and hauled them away (in this case 10 miles). The cans were emptied there, scalded and rinsed in boiling water, and returned the next day. The garbage was fed to hogs. The entire process was arranged for and inspected by the writer, who was Sanitary Inspector.

The paper was collected and delivered to the Quartermaster who looked after its baling and disposal. Although an incinerator was provided, it was not used.

Each kitchen was supplied with a grease-trap which was cleaned every morning, the grease being stored in barrels with fly-proof covers. The grease was afterward disposed of by the Quartermaster.

The sewage treatment plant consisted of septic tanks, a contact bed, and final disinfection. The twin septic tanks were covered and had a capacity of about 8 hours' flow, but due to the fact that all the flow was during 16 hours of the day, actual storage was somewhat less than 6 hours when the plant was placed in operation. Scum rapidly accumulated and reduced this storage to half, resulting in a very inefficient arrangement.

The contact bed was dosed by a siphon, but the bed was very small and the dosing tank very large, which resulted in the bed becoming full before the dosing tank emptied; some of each dose, therefore, was only strained instead of aerated.

There was no final settling or chlorine contact tank; the effluent from the contact bed was dosed as it passed under the chlorinator house. The chlorinator was a Wallace and Tiernan Type "A" Manual Control machine which was designed for a uniform flow rather than a pulsating flow from a contact bed.

Mr. Perry. The population contributing to this plant was somewhat more than 1 000, within 10% of the estimated population. The daily per capita water consumption was approximately 140 gal., although four times that quantity was available and the sewage plant was certainly not designed for more than 40 gal. The sewage plant was poorly designed and indicated little or no knowledge of the water supply.

The writer apprehended operating difficulties when the plans were shown him by the Construction Engineer, and took the matter up with Washington immediately, but the design was never changed. Although the Construction Engineer had to build the plant in accordance with plans and instructions from Washington, he secured permission to use about 1 000 ft. of sewer pipe for an outfall line to carry the plant effluent far enough away to prevent a local nuisance. As this effluent flowed about five miles through an open ditch, with almost no dilution, before being discharged into the river, it is plain that some complaints would follow. There was no complaint, however, while the plant was under the writer's observation, but it is seen that operation difficulties were present in that:

1.—Insufficient sedimentation was obtained; the sludge was not digested and was hard to handle.

2.—The contact bed operated merely as a strainer (analysis indicated that it did no good whatever).

3.—The chlorinator and appurtenances were of the wrong type, resulting in inefficiency.

No relief was obtainable, and the operator was responsible for the quality of the effluent. This constitutes the writer's personal experience with army sewage plant operation in the United States. Although no complaints were filed in this case, the plant was far from efficient, a fault for which the operator was not responsible.

The experiences of a single observer are far too narrow for general statements; a soldier sees only the details immediately before him, and never has an opportunity to obtain a knowledge of comprehensive plans or the difficulties under which the officer at Headquarters has to contend. If based entirely on personal experience and observation, the writer's opinion concerning the activities of the Construction Division would be entirely different from the fair estimate that has been made possible by Maj. Doten's paper. His experience was similar to hundreds of other officers and, no doubt, the information contained in this paper will throw a new light to some of the critics of the War Department.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

WATER SUPPLY FOR THE CAMPS, CANTONMENTS, AND OTHER PROJECTS BUILT BY THE CONSTRUCTION DIVISION OF THE UNITED STATES ARMY

Discussion*

By Messrs. Lynn E. Perry and Asa E. Phillips.

Lynn E. Perry,† Assoc. M. Am. Soc. C. E. (by letter).‡—The Society is much indebted to Col. Maury for this valuable paper. Indeed, the country is indebted to him and his capable and patriotic corps of assistants comprising the Construction Division of the Quartermaster Corps. Mr. Perry.

Considerable courage was needed to adopt so low a per capita daily consumption of water as 55 gal. The writer is positive that not many data were available concerning the water consumption of a soldier as contradistinctive to a civilian; and it could only have been Col. Maury's extremely broad experience and ripe judgment that led him to adopt so economical and, at the same time, so adequate a figure.

The writer's experience with the water problem at the large cantonments in the United States has been that of consumer only. He was, however, for a short time associated with the Aviation Section of the Signal Corps at one of the fields under construction. This field was designed for six aero squadrons and proportionate medical and quartermaster detachments, a total of about 1 018 officers and men. The maximum population during the writer's stay was 1 066.

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* Discussion of the paper by Dabney H. Maury, M. Am. Soc. C. E., continued from October-November-December, 1919, *Proceedings*.

† Easton, Pa.

‡ Received by the Secretary, December 8th, 1919.

Mr. Perry. The water supply was lifted from four wells, about 300 ft. deep, into a concrete reservoir; thence it was pumped to a tank 135 ft. high. Aviation fields are usually located on fairly level sites, and this field was no exception. A geological investigation indicated that the water entered the stratum at an outcrop about 40 miles north of the field; the quality was good.

During construction the engineer was persuaded to sink one well to a lower stratum, the quality of the water from which was known to be excellent and was being used by a near-by large city. The well, however, would yield only about 67 gal. per min. and was drawn to the shallower stratum, the orders being to sink four wells each yielding 100 gal. per min.

Thus, four wells were provided, each yielding 100 gal. per min., or a total capacity of more than 500 000 gal. per day, for a population of about 1 000. Either well would supply 140 gal. per capita per day which, incidentally, was about the consumption. The entire system was constructed of cast iron and the tank was made of steel. Although the writer advised an emergency chlorinator, none was provided during his stay. During construction, when an inferior quality of water was being used, an emergency hypochlorite plant had to be provided.

The writer's attention was particularly drawn to the sanitary precautions mentioned in the paper. He has always been an enthusiastic advocate of emergency chlorinators, especially where the water is of questionable quality, and believes that these were finally provided at all the cantonments and camps in this country.

The covering of reservoirs and tanks to prevent pollution and the growth of algæ is also very important. The writer had considerable difficulty in obtaining materials for this purpose in France; at least one reservoir, that for Kerhuon Hospital Center, near Brest, was covered with canvas, after having been in use for about one year.

It would be instructive and interesting to have a discussion from some one connected with the Construction Division of the Signal Corps, in connection with the experience and activities of that body during recent hostilities. A paper presenting the work of the Water Service in France would also be timely, and the writer trusts that such a paper will be written.

Mr. Phillips. Asa E. Phillips,* M. Am. Soc. C. E. (by letter).†—In the discussion of this admirable paper on water supply for camps and cantonments, which only briefly outlines the great work done by Col. Maury and his staff, there should be recorded, with just estimate of its paramount value, the remarkable rapidity with which results were achieved in completing and putting into operation safe, adequate and reliable

* Washington, D. C.

† Received by the Secretary, December 18th, 1919.

water supply systems for these extraordinary military establishments, which results could only have been accomplished by rare good judgment, reinforced by instant decision and exceptional foresight. In reading this paper one gets only a glimpse between the lines of these qualities on which the success of this great work depended so completely. Mr. Phillips.

Perhaps one of the war expressions that will linger longest in the minds of many is "quantity production"—so often a Utopia not reached until after Armistice Day. It should be recorded, however, in the annals of Engineering, that of all war activities none approached the great achievement of the Construction Division of the War Department in instantly striding into quantity production from the day the organization was set up; and this could only have been due to the extraordinary quality of the personnel of the commissioned officers on Gen. Marshall's staff. In the remarkable results achieved, Col. Maury contributed much, and that was of vital significance.

In many ways this work on the water supply for cantonments and camps is of permanent value. The wide experience it has given in the use of wood-stave pipe, in standards of lay-out and construction, in safeguarding water supply, and enlightening work in the way of fire protection, has left the leaven of sound practice in the far reaches of the country.

Thus far, much of the discussion on this paper has been devoted to consideration of the unit allowance of 50 gal. per capita per day, and, occasionally, there occurs a lament at the average per capita daily consumption of the larger cities. "One of the greatest economic municipal crimes of the United States", says P. H. Norcross, M. Am. Soc. C. E., in his discussion,* "is the extravagant use of water. In no city is this emphasized more acutely than in Washington, D. C., where the daily consumption runs as high as 150 to 160 gal. per capita, and where practically 60% of the total water furnished is used by Government Departments, for which no direct charge is made. The remaining 40%, which is used by the private consumer, bears the entire burden."

There is much truth in what Mr. Norcross says, and yet his data set forth the situation so imperfectly that it may be well to record, as accurately as is now possible, some figures as to water consumption at Washington. The average daily consumption for the fiscal year ending June 30th, 1919, was 64 428 356 gal. distributed about as follows:

Domestic (dwellings and apartments), 88% metered	20 000 000	gal.
Large private consumers, all metered	12 000 000	"
Municipal buildings and works	3 500 000	"
U. S. Government	25 000 000	"
Unaccounted for	3 900 000	"

* *Proceedings*, Am. Soc. C. E., August, 1919, p. 651.

Mr. Phillips. From this it will be seen that the domestic consumption is 31% of the total, large consumers 19%, municipal 5%, and the U. S. Government, 40 per cent. The domestic consumption is about 45 gal. per capita, and the total consumption about 142 gal. per capita.

The total revenue from water rates for this fiscal year was $782 159.36, derived about as follows:

Domestic (dwellings and apartments)............	$560 000.00
Large consumers	222 000.00
Municipal	None
U. S. Government...............................	None

Thus, it is seen that the domestic consumers pay 72% of the total tax for 31% of the water; the large consumers pay 28% of the tax for 19% of the water; and the United States pays nothing for 40% of the water.

Now, it is quite apparent from these figures that Washington can lay no claim to pre-eminence in the category of "municipal crimes" of this character. Whatever there may be of undue usage of water, it certainly cannot be charged to the domestic consumer, who modestly pays three-quarters of the tax and receives one-third of the water, or to the municipality.

With this unbalanced adjustment, if it were not for the revenue derived from the large consumers, sufficient funds would not be available to operate the Water Department, and, perhaps, this condition has permitted somewhat greater liberality as to usage by the large private consumer, the only other source of revenue, since the United States declines to pay anything. As a tax on municipal use must come from the taxpayer, and only means taking money out of one pocket to put it into another and but little increase in revenue would be had in this way, it presents small opportunity for relief, although doubtless sound in principle.

The only large manufacturing establishments in Washington belong to the United States Government. Of these, the Naval Gun Factory, the Government Printing Office, and the Bureau of Engraving and Printing use about 40% of the total Government consumption, the remainder being used in other Federal establishments, such as hospitals, laboratories, and offices. Much of this usage may well be considered wasteful, but the total must inevitably be large.

Probably no other city in the country has a more evenly distributed domestic consumption throughout its population, so that the average daily domestic consumption must be considered to be quite low, when one takes into account the character of the population, as well as the physical characteristics of the National capital.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

PRESSURES IN PENSTOCKS CAUSED BY THE GRADUAL CLOSING OF TURBINE GATES

Discussion*

By Norman R. Gibson, M. Am. Soc. C. E.†

Norman R. Gibson,‡ M. Am. Soc. C. E. (by letter).||—In closing the discussion of his paper, the writer desires, first of all, to make amends, as far as possible, for the injustice unknowingly done to Mr. L. Allievi by the reference to his formula on the diagrams and in the text of the paper. As pointed out by Mr. Halmos, the formula designated by the writer as Allievi's is only one of several contained in his complete work. While "ignorance excuseth none", the writer can only plead, in extenuation, that he did not read Allievi's work, because he could not find an English translation of it, but was led to believe, by the frequent references to "Allievi's formula" in English literature on the subject, that the formula quoted was, in fact, the one and only equation derived by Allievi. The writer was the more completely led astray by a lengthy reference to this formula in a paper published in the *Transactions* of the Society, from which it could not but be inferred that the author had read the work of Allievi in the original language. It is inconceivable how any one, having read it, could so overlook the most important part of Allievi's work. Mr. Gibson.

The writer is indebted to Mr. Halmos and Mr. Kurtz for having brought to light some further formulas of Allievi, as published in the German and Italian languages. Mr. Halmos states that the writer's

* Discussion of the paper by Norman R. Gibson, M. Am. Soc. C. E., continued from August, 1919, *Proceedings*.

† Author's closure.

‡ Niagara Falls, N. Y.

|| Received by the Secretary, December 30th, 1919.

Mr. Gibson. solution agrees in every particular with that of Allievi, and Mr. Kurtz finds a close agreement in an arithmetical example.

The identity of the results obtained by the Allievi equations with those derived from the writer's may be proved as follows:

Considering first Equation (3) presented by Mr. Halmos on page 555,* it should be noted that Mr. Halmos had the writer's attention drawn to a mistake in his definition of ψ (t). This symbol stands for the ratio of the instantaneous area of discharge to the area of the pipe (not the area of the gate-opening at the time, $t = 0$).

The two nomenclatures are as follows:

Halmos.		Gibson.
$\psi\ (t) = \left(1 - \frac{t_n}{T}\right) \frac{B_0}{\sqrt{2\ g}}$	$=$	$\sqrt{\frac{S_{t_n}\ g}{2\ a^2}}$
y_0	$=$	H_0
y	$=$	$H_0 + h_{t_n}$
H	$=$	$H_0 + \frac{a\ V_0}{g}$
c_0	$=$	V_0
C	$=$	V

On page 556,* Mr. Halmos states that F (t), found in the first interval, should be substituted for (f) in Equation (3), in order to obtain the value of y for every subdivision of the second interval.

Using the subscript n of the writer's notation, the relation between F (t) and (f), may be expressed by the equation:

$$f\ (t_n) = F\ (t_{n-1})$$

Again, on page 556,* Mr. Halmos gives:

$$F\ (t) = \frac{a}{g}\ (c_0 - C) - f$$

Substituting the subscript, n, and the writer's notation for c_0 and C,

$$F\ (t_n) + f\ (t_n) = \frac{a}{g}\ (V_0 - V_{t_n})$$

$$\therefore 2\ \frac{a}{g}\ (V_0 - V_{t_n}) = 2 \left\{ F\ (t_n) + F\ (t_{n-1}) \right\} \ldots\ldots\ldots\ldots (1)$$

and, similarly,

$$2\ \frac{a}{g}\ (V_0 - V_{t_{n-1}}) = 2 \left\{ F\ (t_{n-1}) + F\ (t_{n-2}) \right\} \ldots\ldots\ldots (2)$$

Subtracting Equation (1) from Equation (2):

$$2\ \frac{a}{g}\ (V_{t_n} - V_{t_{n-1}}) = 2 \left\{ F\ (t_{n-2}) - F\ (t_n) \right\}$$

* *Proceedings*, Am. Soc. C. E., August, 1919.

If each term in the writer's general expression for R is now expanded in terms of V, then: Mr. Gibson.

$$R_{t_n} = R_0 + 2\frac{a}{g}\left\{(V_{t_n} - V_{t_{n-1}}) + (V_{t_{n-2}} - V_{t_{n-3}}) + \ldots\ldots\ldots\ldots\right\}$$

and, by analogy:

$$R_{t_n} = R_0 + 2\left[\left\{F(t_{n-2}) - F(t_n)\right\} + \left\{F(t_{n-4}) - F(t_{n-2})\right\} + \ldots\ldots\right]$$

and, by cancellation:

$$R_{t_n} = R_0 - 2\,F(t_n)$$

and

$$R_{t_{n-1}} = R_0 - 2\,f(t_n)$$

By substitution of the above values and by reference to the relation of terms in the paper, Allievi's Equation (3), as given by Mr. Halmos on page 555,* may be written for any interval, n:

$$(H_0 + h_{t_n})^2 - 2\,(H_0 + h_{t_n})\left(H_0 + R_{t_{n-1}} + \frac{S_{t_n}}{2}\right) + \left\{H_0 + R_{t_{n-1}}\right\}^2 = 0$$

and by solving this quadratic:

$$h_{t_n} = \frac{1}{2}\left\{(S_{t_n} + 2\,R_{t_{n-1}}) \pm \sqrt{St_n\,(St_n + 4\,R_{t_{n-1}} + 4\,H_0)}\right\}\ldots(3)$$

which is the writer's general expression, similar to Equation (10) on page 190,† for h at any time in any interval.

Mr. Kurtz has presented the general Allievi formula in somewhat different form from that used by Mr. Halmos, in that the values of V and h at the interval points, as contained in the writer's values of R, are eliminated, and the labor of computation is thereby reduced. The writer's equations, however, require no more heed to be given to "magnitude and direction of waves in the computations" than do the Allievi equations. Mr. Kurtz's remark in this connection, on page 568,* probably refers to the explanation of the work of arithmetic integration which preceded the writer's derivation of his formulas. Mr. Kurtz's Table 6 of arithmetic errors indicates merely the difference in the results that might be obtained by two computers. The results given by the Allievi formulas are identical with those of the writer.

The elimination from the writer's equations of V and h at the interval points may be accomplished in the following manner: Referring to the equations on page 190,† the expression for R_{t_1} may be equated to that part of the equation remaining after R_{t_1} has been substituted in place of $\frac{a}{g}\,V_1 + h_1 - C_{t_1}$.

* *Proceedings*, Am. Soc. C. E., August, 1919.

† *Proceedings*, Am. Soc. C. E., April, 1919.

Mr. Gibson.

Thus, in general,

$$R_{t_{n-1}} = \frac{a}{g}\left(1 - \frac{t_n}{T}\right) B_0 \sqrt{H_0 + h_{t_n}} + h_{t_n} = \frac{a}{g} V_{t_n} + h_{t_n}$$

$$= \frac{a}{g} V_{t_n} + \frac{a}{g}(V_n - V_{t_n}) + h_{n-1} - C_{t_{n-1}} = \frac{a}{g} V_{t_{n-1}} - h_{t_{n-1}}$$

$$= \frac{a}{g}\left(1 - \frac{t_{n-1}}{T}\right) B_0 \sqrt{H_0 + h_{t_{n-1}}} - h_{t_{n-1}}$$

$$= \sqrt{S_{t_{n-1}}(H_0 - h_{t_{n-1}})} - h_{t_{n-1}} \ldots\ldots\ldots\ldots\ldots (4)$$

If this value of $R_{t_{n-1}}$ is substituted in the writer's equations in place of the value given in the nomenclature on page 188,* the labor of solving problems by the formulas will be lessened.

Mr. Johnson's discussion† contains a considerable amount of new matter which will be found most helpful in solving problems of the kind under consideration. His remarkably simple and concise presentation of the fundamental principles of this subject and his derivation of the expression for $\frac{h_n}{H_0}$, the ratio at any time of the rise of pressure to the net head, are particularly noteworthy and important. His chart of limitations and general water-hammer chart for uniform gate-closure make it possible, first, to see at a glance in Fig. 12, where it is safe to apply the general logarithmic curve given by Allievi's Formula (4), which is Mr. Johnson's Equation (7), and, second, to obtain from Fig. 13, the ratio of $\frac{h_{max.}}{H_0}$. As pointed out by Mr. Johnson, his Equation (7) covers a wide range of conditions, and it will often be found convenient to use this equation wherever it applies.

Mr. Creager's desire to know more about the application of water-hammer formulas to pipes of varying diameter‡ will be appreciated by every one who studies this subject. Needless to say the problem is a complex one, but it seems certain that the fundamental relations that have been developed herein can be applied not only to this but to any water-hammer problem. The point brought out by Mr. Creager that the friction head at the gate is not constant during the period of $\frac{L}{a}$ is worthy of consideration, but the writer would suggest that the change in friction head, being a change in pressure, cannot traverse the length of the pipe at a rate faster than the velocity, a. In any event, even though the friction head does vary during the interval periods, it would seem that the net result throughout the closing time

* *Proceedings*, Am. Soc. C. E., April, 1919.

† *Proceedings*, Am. Soc. C. E., August, 1919, p. 559.

‡ *Proceedings*, Am. Soc. C. E., August, 1919, p. 570.

Mr. Gibson.

would be that the friction and velocity heads are recovered proportionately to the rate at which the velocity of flow is destroyed.

Near the top of page 571,* Mr. Creager misquotes the assumption made on page 191† of the paper. The friction head at the gate was assumed to be proportional to the square of the velocity of flow, not the velocity "adjacent to the gate."

During the past year many experiments on pressure-rise have been made by the writer with specially designed apparatus. Most of the experiments, however, were made in connection with his new process for the measurement of the flow of fluids in closed conduits, and as this work continued until late autumn, it has been necessary to postpone until next year the particular experiments that have been proposed to show the relation between gate motion and pressure-rise covered by the formulas. As soon as possible the results of these experiments will be made available for publication, and in assembling the data Mr. Anderson's request‡ for full particulars will be remembered.

In reply to the criticism of Mr. Warren,‖ it may be observed at once that the vital importance of including the initial static head among the factors that determine the maximum rise of pressure, cannot be considered in the same class as "odd cents in million dollar estimates". The large increase in water-hammer for low heads over that for high heads when the gate motion is uniform, is caused by the influence of the initial head.

Mr. Warren cannot obscure the points at issue by clouding the discussion with conjectures as to whether uniform gate motion or the gate motion he has assumed, but not defined, "is nearer the average gate motion". The vagaries of gate motions are not under consideration, as is clearly stated on page 176.† The problem considered is the rise of pressure following any given gate closure, and, for this purpose, in deriving the formulas, uniform gate motion has been assumed. Diagrams of non-uniform gate motion were shown and attention was drawn to the effect of such non-uniform motion on the shape of the pressure-time diagram. In all practical cases, actual conditions will be determined and, as Mr. Johnson says, "the element of judgment must enter as usual". Mr. Warren's statement that his formula is based on a certain prescribed shape of the pressure-time diagram which may be produced by a special, though undescribed, performance of the gate, condemns his formula for general use, because it is impossible to adapt it to any particular gate motion. Indeed, what he says of his own arbitrary diagram is equally true of any form whatever which gives a value of the maximum pressure-rise greater than the mean effective pressure-rise and which encloses a proper impulse area.

* *Proceedings*, Am. Soc. C. E., August, 1919.

† *Proceedings*, Am. Soc. C. E., April, 1919.

‡ *Proceedings*, Am. Soc. C. E., August, 1919, p. 566.

‖ *Proceedings*, Am. Soc. C. E., August, 1919, p. 564.

Mr. Gibson. For uniform closure, Mr. Warren's formula always leads to errors on the wrong side, that is, it gives less than the true value. In the region, pointed out in the paper, where it is approximately correct, and when the first interval is a small proportion of the closing time, as it frequently is in ordinary cases, this formula gives a result close to the value of the mean rise of pressure which can be determined by the simple expression, $\frac{L\,V}{g\,T}$.

Mr. Warren questions the assumption that pressure waves are perfectly reflected from the slowly closing gate. The question implies a misconception of the nature of the waves themselves. They are not of a substance that rebounds like a rubber ball, but are conditions of the water column at various times at different points along the pipe line. When a wave is started by a movement of the gate, the water is put into a state of super-normal pressure and it remains in this condition at the gate until the wave has traversed the length of the pipe to the origin and back again. When the wave has returned to the gate, the state of super-normal pressure there is converted to one of sub-normal pressure and the water there remains in this condition until the wave has again traversed the distance to the origin and back, whereupon the condition at the gate again changes to a state of super-normal pressure, and so on. At points along the pipe the changes of condition occur in the same sequence, except that a state of normal pressure exists for a time between the periods of super-normal and sub-normal pressures. When the gate is gradually closing, the algebraic sum of the innumerable infinitesimal waves (super-normal pressure being considered positive and sub-normal pressure negative) fixes the pressure that exists at the gate at any time during the closure.

The authority for the assumption that the flow of water in the pipe does not affect the wave is to be found on page 176* in the following quotation from Miss Simin's translation of Joukovsky's work:

"If the water column continues flowing, such flow exerts no noticeable influence upon the shock pressure. In a pipe from which water is flowing, the pressure wave is reflected from the open end of the pipe, in the same way as from a reservoir with constant pressure."

Finally, it may be stated definitely that, as an empirical rule for convenient use, Mr. Warren's formula is quite untrustworthy, and as an equation showing the relation between velocity destroyed and rise of pressure, it is fundamentally and inherently wrong.

* *Proceedings*, Am. Soc. C. E., April, 1919.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

CHARLES MATTATHIAS JACOBS, M. Am. Soc. C. E.*

DIED SEPTEMBER 7TH, 1919.

Charles Mattathias Jacobs was born at Hull, Yorkshire, England, on June 8th, 1850, and died at his home at Laugharne, South Wales, on September 7th, 1919.

He was the ninth in a family of fourteen born to Bethel and Esther Jacobs. His father was a member of a family long established in Hull, a well known and highly honored merchant of that city.

Mr. Jacobs was educated by private tuition and, in 1866, at the age of 16, was articled as a pupil in the arts of mechanical and structural engineering with Messrs. Charles and William Earle, one of the leading ship and engine building firms on the northeast coast of England. With this firm Mr. Jacobs served his five-year term of apprenticeship, obtaining a thorough knowledge of all the trades involved in ship and engine building, as well as in the design of engines and structures.

This pupilage in practical work was then the usual British system of technical training. Throughout his long service as a professional engineer, Mr. Jacobs' practical understanding of, and his judgment in solving, engineering problems always reflected that early training.

In 1871, on the completion of his apprenticeship, he was sent by Messrs. Charles and William Earle to China to put up some bridges which they had contracted to build and erect.

On his return to England, Mr. Jacobs decided to follow the profession of a marine engineer and to that end went to sea in the Merchant Service for between two and three years, the period necessary to obtain the British Board of Trade certificate as First-Class Marine Engineer.

In 1876 he opened an office in Cardiff, South Wales, as a Consulting Engineer, specializing in marine engineering.

In this same year he married Frances H. M., daughter of the late John Fry, of Penarth, a leading colliery operator and shipowner. His widow survives him.

Soon after this, he was appointed Surveyor to Lloyd's Register of Shipping at Cardiff, and he held this office for a few years. During this period he became recognized as an expert and authority in a business in which Cardiff and Newport stood pre-eminent, namely, the briquetting and consequent utilization, of the slack coal-dust from the non-coking coals of South Wales and Monmouthshire.

* Memoir prepared by J. V. Davies, M. Am. Soc. C. E.

On December 1st, 1885, he was elected a Member of the Institution of Civil Engineers. In 1887, Mr. Jacobs removed to London, where he opened a Consulting Engineer's office in partnership with Mr. Herbert Barringer, under the firm name of Jacobs and Barringer. This connection, which broadened the scope of his engineering work, continued until his death.

In 1888, the late Austin Corbin, who was then President of the Long Island, the Philadelphia and Reading, and the Elmira, Cortlandt and Northern Railroads, besides having wide interests in other organizations and subsidiary companies, became deeply interested in the possibility of using the culm or waste produced in the crushing and sorting of anthracite coal in the fields of the Philadelphia and Reading Coal and Iron Company. While in Europe in that year, Mr. Corbin consulted with Mr. Jacobs as to the possibilities of this development and invited him to come to the United States, which he did early in 1889. This was the beginning of the long and close association between Mr. Corbin and Mr. Jacobs, by which Mr. Jacobs became directly identified as Consulting Engineer with all the engineering problems of the various interests controlled by Mr. Corbin.

The most pressing problem at that time was that of an improved terminal for the Long Island Railroad. Mr. Jacobs took up the study of an extension of the Long Island Railroad from its terminals in Brooklyn and Long Island City. In co-operation with Samuel Rea, M. Am. Soc. C. E., of the Pennsylvania Railroad, he developed a plan for the extension of the Brooklyn lines by tunnel under the East and North Rivers, which would give passenger connection direct to the Pennsylvania Railroad Company's Jersey City terminal. One element in these studies was the removal from Atlantic Avenue, Brooklyn, of the surface tracks of the Long Island Railroad. The preliminary studies and estimates for doing this by elevating and depressing the railroad were made under the direction of Mr. Jacobs, and the work was later carried out by his partner, J. V. Davies, M. Am. Soc. C. E., as Chief Engineer to the Board for the Atlantic Avenue Improvement. This work, and the other studies made for the improvement of the Long Island Railroad, initiated Mr. Jacobs' connection with the rapid transit situation in New York City.

In 1891, Mr Jacobs opened an office as Consulting Engineer in New York City, his Chief Assistant being Mr. Davies, with whom he later entered into partnership. The company was finally organized as Jacobs and Davies, Incorporated, and continued without a break until the end of 1916, when Mr. Jacobs retired from practice in the United States.

In 1892, he undertook for the East River Gas Company the design and supervision, as Chief Engineer, of the construction of a tunnel having an internal diameter of 10 ft. 2 in. to connect the company's plant at Ravenswood, Long Island, with the Borough of Manhattan.

This tunnel starts at the foot of Webster Avenue, Long Island City, and ends at the foot of East 71st St., New York City, passing under both channels of the East River and under Blackwells Island. The work was a notable achievement for Mr. Jacobs. Soon after the tunnel had been started, a seam of rotten rock giving direct access to the river was encountered, the contractor abandoned the work and Mr. Jacobs took it over on behalf of the Company, installed a tunneling shield, and finished it with his own forces after many and serious difficulties had been met and conquered.

This was the first tunnel to be finished under either the North or East Rivers, although others had been begun at an earlier date under both rivers. The air pressure used was very high, reaching 48 lb. per sq. in. (above the normal), and this is believed to be the first case in which extensive rock blasting was done under compressed air.

In 1895, Mr. Jacobs was appointed by the bondholders of the Company owning the then unfinished and abandoned Hudson River Tunnel at New York City, as one of a committee of three to examine and report on the condition of and possibility of finishing that work. As a result of this investigation, and after long delay in re-organizing the finances of the old concern, a new company was formed, under the presidency of Mr. William Gibbs McAdoo, known as the New York and Jersey Railroad Company, which took over the old work and carried on the enterprise. This was the nucleus about which the present Hudson and Manhattan Railway System of passenger railroad service between New York City and Jersey City has been built up and which now acts as the down-town New York distributing terminal of the Pennsylvania Railroad and also as the up-town and down-town New York terminals of the Delaware, Lackawanna and Western Railroad and the Erie Railroad.

The design and construction of this important system of tunnels across the North River and in New York City and Jersey City, involving many unprecedented problems both as regards design and execution, were carried out for the company by Mr. Jacobs as Chief Engineer, with his own designing, engineering, and construction forces. The construction of this system, as it stands to-day, was finished in 1910. By the completion of the "Old North Tunnel", begun in 1874, and dogged by persistent ill luck until Mr. Jacobs took over the work in 1902, the conquest of the North River was achieved, and Mr. Jacobs, of all his successes, always looked back with the greatest pride to the fact that on March 11th, 1904, he was the first man to have crossed, dryshod, beneath the great North River, from New Jersey to New York City. The work of tunneling the North River for this company was described by Mr. Jacobs in a paper* presented to the Institution

* *Minutes of Proceedings,* Inst. C. E., Vol. CCXXXI (Paper No. 3859).

of Civil Engineers on February 22d, 1910. For this paper, the Council of the Institution gave him its premier award, the Telford Gold Medal.

In 1898, Mr. Jacobs prepared the plans and specifications and awarded the contract for the Tredegar Dry Dock at Newport, Monmouthshire, on the western side of the River Usk. This dry dock is 708 ft. long and 65 ft. wide at the entrance. It can take a ship of 12 000 tons, and is divisible in two sections by middle gates, so that two ships of 7 000 tons each can be docked at the same time. Many serious difficulties, due to the nature of the ground, were met and successfully overcome and the work* was finished in 1903.

The other great New York project with which Mr. Jacobs' name will be forever linked is that which brings into New York City the terminal of the Pennsylvania Railroad. It is impossible here to do more than mention that Mr. Jacobs was the Chief Engineer of the North River Division of this work, and thus had direct charge of the designs and construction of all that part which lies between the Terminal Station and the Western Portal of the tunnel through the Bergen Hill. The length of the Division is 14 280 ft., all in tunnel and all providing for two lines of track. The material penetrated ranged from the softest silt to the hardest trap rock, with every possible variety lying between the two. The work is described fully in papers by Messrs. Raymond, Jacobs, Noble, Gibbs, and members of the staff.†

Mr. Jacobs' own paper‡ describes fully his personal connection with this work dating from his consultation in London in 1901 with Mr. Cassatt, then the President of the Pennsylvania Railroad. This paper contains also a most interesting sketch of the events which preceded and led to the inception of this great scheme. One thing, however, must be made clear as it is only touched upon most lightly in his own account, and that is, that without the assurance given by Mr. Jacobs' invention to provide support, if such should be found necessary in the North River silt, for the structure and tracks of tunnels, by an internal bridge construction within the tunnels themselves, supported by piers or piles sunk to firm foundations, it is unlikely that the management of the Pennsylvania Railroad would have ventured on the uncertainties of building the great main line tunnels in this silt. Protracted and exhaustive tests during the construction period proved that these supports were not needed, but the value of their conception as an assurance to those who planned this bold feat cannot be over-estimated.

Both these undertakings, involving the crossing of the North River by six different tunnels, were carried out simultaneously by Mr. Jacobs between 1901 and 1910. Many of the problems were literally unprecedented, and to the pioneer solution of these Mr. Jacobs brought

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* *Minutes of Proceedings*, Inst. C. E., Vol. CLXVII (Paper No. 3646).

† *Transactions*, Am. Soc. C. E., Vols. LXVIII and LXIX.

‡ "The North River Division," *Transactions*, Am. Soc. C. E., Vol. LXVIII, p. 32.

his ever practical viewpoint, his convincing personality, his indomitable perseverance, and the keen edge of his enthusiasm.

Many other works of large size and great difficulty have been carried out under Mr. Jacobs' general direction, among which are the following, stated more or less in chronological sequence.

He was closely identified with the oil industry and built many oil storage installations in Great Britain and elsewhere, one of which was a pipe line for the Burmah Oil Company from Rangoon to Yenangyat. This line consists of about 270 miles of 10-in. and 30 miles of 4-in. pipe, between the wells and the seaboard, together with pumping stations and tank equipment. The surveys were made in 1902 and the installation was finished in 1908.

From 1907-11, he had charge, as Consulting Engineer to Messrs. Daydé and Pillé, Contractors, of the tube tunnels driven by shield under compressed air below the River Seine and the Place de la Concorde, in Paris.

From 1910-15, the construction of the Astoria Tunnel, 4 662 ft. long and 275 ft. below the waters of the East River, was accomplished. This tunnel is used to contain two cast-iron mains, 6 ft. in diameter, by which gas is conveyed from the plant of the Astoria Light, Heat, and Power Company to East 132d Street, The Bronx. This tunnel is 20 by 20 ft. in cross-section and gave rise to what was probably the worst problem in tunneling under normal air pressure yet presented in New York City. This work, which was designed and carried out by Mr. Jacobs' own forces, has been fully described.*

From 1910 to 1913, the construction of the Hales Bar Lock and Dam across the Tennessee River near Chattanooga, Tenn., was carried out by Mr. Jacobs' firm. In this case, in order to obtain secure foundations in a limestone rock, honeycombed with caverns and pockets, very large monolithic caissons had to be sunk under pneumatic pressure.

In 1912-13 the construction of the Laxaxalpam Aqueduct Tunnels of the Mexican Light and Power Company was completed by Mr. Jacobs' firm with its own forces after the work had been at a standstill on certain essential portions, owing to the severe physical difficulties, for more than a year. This work comprised a total length of 20 miles of tunnel in a mountainous part of the State of Puebla, Mexico, and notwithstanding serious physical difficulties, due both to the geological formations and the remote and mountainous nature of the country, was finished within the time desired.†

Mr. Jacobs' practice kept in close touch with marine work to the end, particularly in ship and engine building. He was responsible for the building of some 84 tank steamships and more than 100 cargo and other vessels.

* *Transactions*, Am. Soc. C. E., Vol. LXXX (p. 594).

† *Minutes of Proceedings*, Inst. C. E., Vol. CC, p. 345 (Paper No. 4123).

Some of the large projects which he fathered, or with which he was connected, are the following:

The location of a railway by which the Long Island Railroad would cross by tunnel under Long Island Sound and connect with the Housatonic Railroad. This would have given a route to Boston, *via* the New England Railroad, and it was thought would form a rival to the New Haven Railroad System. The absorption of the New England lines by the New Haven Company stopped this project.

At the same time, however, the contemplated scheme necessitated a suitable terminal station in New York City, on Manhattan Island, involving the crossing of the East River, with yards and a terminal adequate for the operation, not only of the local traffic of the Long Island Railroad, but also the through business of this projected line with its connections. Studies were then made as to the feasibility of a tunnel crossing in the vicinity of the existing Long Island Railroad Terminal, at Long Island City, but it then appeared that the cost of such necessary terminals in the East 34th Street district would be so high as to be prohibitive.

At this juncture, Mr. Corbin was offered by the late Dr. Thomas Rainey a franchise he held for a bridge structure to cross the East River between Ravenswood, on Long Island, and the foot of East 64th Street, New York City. After extended negotiations and investigations, this franchise was taken up by interests associated with the Long Island Railroad, and notwithstanding the withdrawal of the New England connection problem, it was considered that the plan of development was necessary to the extension of the Long Island Railroad itself, and, consequently, Mr. Jacobs was instructed to proceed with the construction of the bridge, terminal, and connections. This work was actually and actively commenced. Foundations for three main piers at the bulkhead lines of the two channels of the East River were built, and contracts for the masonry and superstructure were awarded, when the accidental death of Mr. Corbin in 1896 suspended all activities, which were never renewed. The appointment of Mr. W. H. Baldwin, Jr., as President of the Long Island Railroad, re-opened the study of the possibility of a terminal which would connect the Long Island Railroad with the Pennsylvania System, which, at that time, had in contemplation the construction of a North River Bridge entry into New York City. The later history of this development and Mr. Jacobs' connection therewith are stated in the *Transactions* of the Society.

The development of Fort Pond Bay at Montauk Point as a terminal for the trans-Atlantic steamship traffic.

The study and report for the French Government on a railway tunnel to cross the Seine near Le Havre to connect the State Railways on either bank.

The study and report for the Moscow-Kazan Railroad on the crossing by tunnel of the Volga River near Nijni-Novgorod.

The report on large reclamation projects for Bombay, India.

The reports on rapid transit development in Montreal, Que., and Toronto, Ont., Canada.

In his personal appearance, Mr. Jacobs was a man of striking presence and of a manner and poise most impressive. As an engineer he combined technical knowledge and good judgment, based on his long experience, with administrative and executive ability of the highest order. Many of his most important works were carried out without the medium of a contractor, with engineering and construction forces organized and directed by him for the owner. His courtesy and consideration to each of his numerous assistants and subordinates on the many projects he undertook during his busy life were never failing. Each of his staff felt that service under him was a valuable experience, and his magnetic personality inspired his men with loyalty and enthusiasm which bound them to him and to his work with bonds stronger than steel.

In his private life, Mr. Jacobs showed the same charming personality and magnetism. He made no enemies, but many close friends who were warmly and loyally attached to him. Writing of him, one of his old friends, a learned and honored Justice of the Supreme Court of New York, says:

"So many incidents of our long association come back to me and through all appear the cool, courageous, cheerful methods of our dead friend. He was at first a stranger in a strange land, but not for long. His ability, his knowledge of men, his courtesy and perseverance made their mark in the community. Tunnels under the rivers are common things nowadays but the pioneers had to struggle hard to make the financiers of twenty-five years ago appreciate the necessity and value of underground transit. * * * I am sorry he has gone. He made a great name for himself in his profession."

He had been a Member of the Institute of Mechanical Engineers since 1876 and a Member of the Institution of Civil Engineers since 1885. He was one of the early members of the Engineers' Club of New York, and had been a member of a number of clubs in New York City before he retired from active business there in 1916. In London, he maintained his membership in the City of London, the Royal Automobile, and the Royal Societies Clubs.

During the World War, Mr. Jacobs was very proud to have been associated with the production of ammunition and ordnance as a member of a Local Production Committee in the South Wales District.

Mr. Jacobs was an enthusiast in the development and use of motor cars. He was one of the early owners of a steam wagon and operated the various types as they appeared. In his religion he was a member

of the Church of England. His home for many years before his death was "The Old Rectory House" at Wimbledon Park, near London. This was an ancient and beautiful Elizabethan house which he enlarged and modernized. During 1919, he had bought a summer home, a place called Glan-y-mor, at Laugharne in Caermarthenshire, South Wales, which was ready for him at the beginning of September. He had only been in this house for a few days when he died as a result of cerebral hemorrhage. His last conscious thoughts were for those near and dear to him, and he left on his long journey with the same calm courage which had always been his. He was buried at St. Augustine's, in Penarth.

His loss leaves a gap which his friends and associates will not fill with his equal, and there is not one who knew him who will not remember him as an inspiring leader, a great engineer, and a thorough man.

Mr. Jacobs was elected a Member of the American Society of Civil Engineers on May 4th, 1904.

RAPHAEL CHART SMEAD, M. Am. Soc. C. E.*

Died November 28th, 1919.

Raphael Chart Smead was born at Washington, D. C., on October 25th, 1859. His father, the late Capt. J. R. Smead, was a graduate of West Point, a soldier in the Civil War, and was killed in the Battle of Bull Run. His grandfather, the late Capt. R. C. Smead, Corps of Engineers, U. S. Army, who was also an Army officer, was killed in the Mexican War.

After his preliminary education in the public schools, Mr. Smead studied under a private instructor for one year.

In 1878, he was employed as Rodman and Instrumentman making railway surveys on the Union Pacific Railway and remained on this work until 1880. Between 1880 and 1881, he was engaged as Instrumentman on the Baltimore and Ohio Railroad; between 1881 and 1882, as Assistant and Resident Engineer on construction on the Norfolk and Western Railroad; between 1882 and 1883, as Resident Engineer on the Grafton and Greenbrier Railroad; and between 1883 and 1885, as Assistant and Resident Engineer on the Baltimore and Ohio Short Line Railroad.

In May, 1885, Mr. Smead was appointed United States Assistant Engineer in the office of the Washington Aqueduct, District of Columbia, where he remained until August, 1905. During that time, he was engaged on the work of building the dam at Great Falls and the tunnel

* Memoir prepared by E. D. Hardy, M. Am. Soc. C. E.

between the Georgetown and McMillan Park Reservoirs, and as Superintendent of Maintenance and Operation of the Washington Aqueduct.

In August, 1905, he was transferred to the Dallas Engineer District where he was employed as U. S. Assistant Engineer until October, 1917. From October, 1917, to February, 1919, he served as U. S. District Engineer, at Galveston, Tex., and from that date until November 28th, 1919, as Principal Assistant Engineer of the Galveston District.

In 1918, Mr. Smead was commissioned a Major in the Engineer Officers' Reserve Corps, but was never called to active duty.

He was a man of pleasing personality and social disposition, who made friends easily and was liked and respected by all his associates. He died very suddenly while engaged on his regular official duties and is survived by his wife and one daughter.

Mr. Smead was elected a Member of the American Society of Civil Engineers, on February 1st, 1905.

GEORGE HIPPESLEY STANLEY STEPHENS, Assoc. M. Am. Soc. C. E.*

Died October 13th, 1918.

George Hippesley Stanley Stephens, the eldest son of Frederick Orlando Stephens, now of The Homestead, Orangezicht, Cape Town, South Africa, was born in Norwich, England, on November 20th, 1882. He was educated at Tunbridge Wells, England, and at the Diocesan College, South Africa. He was articled to his father, a Civil Engineer from 1900 to 1905.

From 1901 to 1908, Mr. Stephens was engaged as Field Assistant and Assistant Engineer by Messrs. G. Pauling and Company, Limited, of London and Cape Town, on the surveys and construction work in connection with the extension of the New Cape Central Railway to Mossel Bay, in Cape Colony, South Africa, and the Stuartstown Railway in Natal. In 1908 and 1909, he was employed by the same firm as Assistant Engineer on the survey of the Bwana Mkubwa ("Star of Congo") Railway, from the Bwana Mkubwa copper mine, in Northwestern Rhodesia, to the "Star of the Congo" Mine, in the Congo State.

In 1909 and 1910, Mr. Stephens served as Assistant Engineer on the construction of the Bwana Mkubwa and Broken Hill Railway, in Northwestern Rhodesia, and from that time until the early part of 1911, he was engaged as First Assistant Engineer on the survey of the Mazoe Railway, also in Rhodesia.

* Memoir prepared by the Secretary from information on file at the Headquarters of the Society.

From 1911 to 1917, he was employed by the South African Railway Administration on the construction of the railway extension from Caledon, Upington, and Carnarvon, and, from that time until his death which occurred at Paarl, South Africa, on October 13th, 1918, Mr. Stephens was engaged on various surveys and investigations for irrigation projects for the Department of Irrigation in the Union of South Africa.

Mr. Stephens' untimely death, from pneumonia supervening influenza, at the age of 36, came as a painful shock to his professional associates and to his wide circle of friends in many parts of Southern Africa. To all of them he was the soul of friendship, and there must still be many who, in the course of the lonely journey by which entry to the Congo from the south was made before the construction of the railway was completed, can recollect his warm welcome and generous hospitality on their way through the illimitable veldt. His largeness of heart indeed was his chief characteristic, and, with it, there went a cheerfulness and constancy that braved every trial, shining even more brightly when the final command came for him, too, to "pass over".

The thorough training which Mr. Stephens had enjoyed under all classes of South African conditions, had eminently fitted him for the highest positions in the service to which he was finally attached, and his early death will prove a loss to the Union in which he had made his home.

Mr. Stephens was married in 1916 to Grace Winifred Taylor, the only daughter of Charles Taylor, of Paarl, who survives him after a brave struggle with the epidemic which, in October, 1918, swept through South Africa.

Mr. Stephens was elected an Associate Member of the American Society of Civil Engineers on December 5th, 1911. He was also an Associate Member of the South African Society of Civil Engineers.

PAPERS IN THIS NUMBER

"GROUTING OPERATIONS, CATSKILL WATER SUPPLY." JAMES E. SANBORN and M. E. ZIPSER. (To be presented February 4th, 1920.)

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AMERICAN SOCIETY

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CIVIL ENGINEERS

VOL. XLVI—No. 2

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

February, 1920

Published by the American Society of Civil Engineers at its Headquarters, 33 West Thirty-ninth Street, New York, the Fourth Wednesday of each Month, except June and July.

Entered as Second-Class Matter, December 14th, 1896, at the Post Office at New York, N. Y., under the Act of March 3d, 1879.
Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3d, 1917, authorized on July 5th, 1918.
Subscription, $8 per annum.

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FEBRUARY, 1920

Edited by the Secretary, under the direction of the Committee on Publications.

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The Reading Room of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, New Year's Day, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 6 P. M.

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Vol. XLVI. FEBRUARY, 1920 No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

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OF THE SOCIETY

SIXTY-SEVENTH ANNUAL MEETING.*

January 21st, 1920.—The meeting was called to order at 10 A. M. in the Auditorium of the Engineering Societies Building; President Fayette S. Curtis in the chair; Chas. Warren Hunt, Secretary; and present, also, about 700 members.

The President announced that he had appointed Ralph H. Chambers, Kenneth Allen, Nathan C. Johnson, J. C. Meem, F. W. Perry, C. D. Pollock, and Harold Tait as Tellers to Canvass the Ballot for Officers for the ensuing year.

* A full report of the Sixty-seventh Annual Meeting is printed on pages 147 to 218 of this number of *Proceedings*.

The Annual Report of the Board of Direction and the Annual Reports of the Secretary and of the Treasurer* for the year ending December 31st, 1919, were presented and accepted.

The Secretary read the report of the Committee to Recommend the Award of Prizes,† and announced that the Board of Direction, in conformity with that report, had awarded the medals and prizes for the year ending July, 1919, as follows:

THE NORMAN MEDAL to Paper No. 1 403, "The Cape Cod Canal", by Wm. Barclay Parsons, M. Am. Soc. C. E.

THE J. JAMES R. CROES MEDAL to Paper No. 1 418, "The Stress Measurements on the Hell Gate Bridge", by D. B. Steinman, M. Am. Soc. C. E.

THE THOMAS FITCH ROWLAND PRIZE to Paper No. 1 417, "The Hell Gate Arch Bridge", by O. H. Ammann, M. Am. Soc. C. E.

THE JAMES LAURIE PRIZE to Paper No. 1 413, "The Manhattan Elevated Railway Improvements", by F. W. Gardiner and S. Johannesson, Members, Am. Soc. C. E.

THE COLLINGWOOD PRIZE FOR JUNIORS to Paper No. 1 409, "Obstructions of Bridge Piers", by Floyd A. Nagler, Assoc. M. Am. Soc. C. E.‡

The Secretary presented the report of the Tellers appointed by the Board of Direction to canvass the final suggestions for members of the Nominating Committee, to represent certain districts, and the following were appointed to serve for two years:

C. Raymond Hulsart............	Representing	District	No.	1
Chas. R. Gow..................	"	"	"	2
William L. Stevenson...........	"	"	"	4
L. P. Wolff.....................	"	"	"	7
Dabney H. Maury...............	"	"	"	8
A. O. Cunningham..............	"	"	"	9
J. C. Stevens...................	"	"	"	12

A progress report of the Special Committee to Codify Present Practice on the Bearing Value of Soils for Foundations was presented by the Chairman, Robert A. Cummings, M. Am. Soc. C. E., in abstract. The report was accepted and the Committee continued.

The second progress report of the Special Committee on Stresses in Railroad Track was presented by Arthur N. Talbot, Past-President, Am. Soc. C. E., who moved that the report be received and printed and the Committee continued. This was duly seconded and carried.

It was moved that the Special Committee on the Regulation of Water Rights be discharged, no report being offered in the absence of its Chairman, F. H. Newell, M. Am. Soc. C. E. This motion was

* See *Proceedings* for January, 1920, pages 89 to 100.

† See page 148.

‡ Transferred from the grade of Junior on May 13th, 1918.

amended and, after considerable discussion in which it was pointed out that it would be unwise to discharge a Special Committee without a final report, an amended motion to refer the matter to the Board of Direction with power was carried.

The Secretary announced that at a meeting of the Board of Direction on January 20th, 1920, it had been decided that the Annual Convention for 1920 would be held at Houston, Tex., in October, as the postponement from June to October would facilitate the business of development by giving time to issue questionnaires and prepare the extensive changes in the Constitution which would be required.

L. D. Rights, M. Am. Soc. C. E., Chairman of the Committee on Arrangements, announced the programme for the excursions and entertainments.

The Secretary announced the following deaths:

William Lyon Browne, of Westmount, Que., Canada, elected Member, January 31st, 1911; died November 24th, 1919.

George Weston, of Chicago, Ill., elected Member, June 5th, 1907; died January 8, 1920.

The Secretary announced the election of the following candidates on January 19th, 1920:

As Members

John Capron Balcomb, New York City
Carroll Alfred Campbell, Middletown, Conn.
James Haworth Eaton, Boston, Mass.
Herbert Vaughan Kent, London, England
Seymour H. Knight, Philadelphia, Pa.
Lynn Orlando Knowlton, Indianapolis, Ind.
Robert Cathcart Latimer, New York City
Philip Gustave Laurson, Montclair, N. J.
Word Leight, Shanghai, China
Byron Wynee Matteson, Ogden, Utah
John Reed, Washington, D. C.
Earl Stimson, Baltimore, Md.
Frank Merrill Weakley, Portsmouth, Md.
Arthur Jacob Widmer, Webster Groves, Mo.

As Associate Members

Arthur Carl Alvarez, Berkeley, Cal.
John Henry Bateman, Ann Arbor, Mich.
Matthew McClung Bird, Nashville, Tenn.
Morris Brown, Pittsburgh, Pa.
Albert Israel Bucheker, Spokane, Wash.
Bertie Harrison Buck, Bogalusa, La.
Edward Hugh Cameron, Gales Ferry, Conn.

Lloyd Angle Canfield, Des Moines, Iowa
George Joseph Francis Carey, Cold Spring-on-Hudson, N. Y.
William Cassius Caye, Jr., Louisville, Ky.
Francis Carlton Colcord, Montcoal, W. Va.
Bernard Labroquere Crozier, Baltimore, Md.
Anthony Joseph Daino, New York City
Charles Bedard Dugan, Columbus, Ohio
Maurice Elias, Paris, France
James Patrick Farrell, Philadelphia, Pa.
George Edward Finck, Baltimore, Md.
Abram Nute George, Los Angeles, Cal.
Edward David Graffin, Newport News, Va.
Irving George Grundel, Avila, Cal.
John Church Hawley, Detroit, Mich.
Frank Fifield Healey, Chicago, Ill.
Trygve Holst-Grubbe, New York City
Clarence Ricker Hopper, Newark, N. J.
Leslie Dillon Howell, Chicago, Ill.
Walter Lawrence Hull, Orange, N. J.
Reginald Heber James, Philadelphia, Pa.
Harry Willey Kenney, Washington, D. C.
Wilmer Ziegenfuss Kline, Philadelphia, Pa.
Oscar William Lanzendorf, San Francisco, Cal.
Hugo Layer, Akron, Ohio
Walter Harrison Lilly, Kansas City, Mo.
Eugene Logan, Spokane, Wash.
Herbert Edward Lowe, Berkeley, Cal.
Raymond Rudolph Lundahl, Milwaukee, Wis.
Thomas Wakefield Macartney, Yakima, Wash.
Clarence William McFerron, Tulsa, Okla.
Raymond Robb Marsden, Hanover, N. H.
James McQueen Martin, Kingstree, S. C.
Harry Lou Miller, Kansas City, Mo.
Perry Kay Miller, Montclair, N. J.
John Donald Mohler, St. Joseph, Mo.
John Marion Nagle, Seymour, Tex.
George Lionel Opper, Kankakee, Ill.
Ernst Leopold Pflanz, Milwaukee, Wis.
Arthur Clifton Pillsbury, Los Angeles, Cal.
Selby Quattlebaum, Roanoke, Va.
Ralph Dennis Rader, Miami, Fla.
Richard Barkley Reasoner, Pocatello, Idaho
Olaf Andrew Reed, Duluth, Minn.
Robert Speirs Saunders, New York City
Thorp Derickson Sawyer, Santiago, Chile

AXEL SOPHUS SCHOYEN, North Plainfield, N. J.
CHARLES AUGUSTUS SHANNON, Nebraska City, Nebr.
SILAS FREDERICK SHAW, Charcas, Mex.
FRED LESTER SIMON, Philadelphia, Pa.
HARRY RALPH STANDIFORD, New York City
CHRISTIAN ERLE STIVER, Cape Girardeau, Mo.
VICTOR GIFFORD THOMASSEN, Paris, France
HARRISON TILGHMAN, Easton, Md.
GUY BRADFORD TREAT, Oklahoma City, Okla.
ALBERT ELLERY WARDWELL, Detroit, Mich.
WILLIAM HENRY WARNECKE, Camp Humphreys, Va.
STEPHEN CARSON WHIPPLE, San Francisco, Cal.
SIDNEY JAMES WILLIAMS, Chicago, Ill.
GEORGE MORRISON WILLIAMSON, Yonkers, N. Y.
THOMAS EARLE WINN, JR., Covington, Va.
LEO JOHN WYKKEL, Kalamazoo, Mich.
GEORGE RICHMOND YOUNG, Milwaukee, Wis.

AS JUNIORS

ARMANDO MANUEL ALVAREZ DE URRUTIA, Havana, Cuba
FLOYD CARSON BEDELL, New York City
MORTIMER FREMONT COON, Sharon, Pa.
WILLIAM THOMAS CROWLEY, Buffalo, N. Y.
MARX HARRY DAYNE, St. Louis, Mo.
JOHN HAWKINS ELLEMAN, Camp Humphreys, Va.
WILLIAM RAYMOND HARTLINE, Houston, Tex.
CASPAR FERDINAND HENNING, Chicago, Ill.
NELSON HARTWELL HUNTLEY, Pittsburgh, Pa.
WILLIAM MARTIN KAISER, Portland, Ore.
PORTER EUGENE PHIPPS MARSHELL, Berkeley, Cal.
HENRY JORDAN PONSFORD, El Paso, Tex.
FRANKLIN ORTH ROSE, Dayton, Ohio
EBERLE UPSHAW STEVENSON, Little Rock, Ark.
EUGENE ROLAND WISEMAN, Altamont, Ill.

The Secretary announced the transfer of the following candidates:

FROM ASSOCIATE TO ASSOCIATE MEMBER

EDMUND JOSEPH BARRY, Camp Dix, N. J.

FROM ASSOCIATE MEMBER TO MEMBER

WILLIAM HENRY ADAMS, Detroit, Mich.
WILLIAM GODFREY ARN, Chicago, Ill.
CHARLES SMITH BILYEU, New York City
PAUL ALEXANDER BLACKWELL, Roanoke, Va.

Edward Gilman Carey, Hinsdale, N. H.
Arnold Goodwin Chapman, Albany, N. Y.
Lloyd Tilghman Emory, Philadelphia, Pa.
Howard Carlton Ford, Denver, Colo.
Howard Whittier Holmes, Oakland, Cal.
Clarence Sylvester Jarvis, Benicia, Cal.
Andrew Lenderink, Kalamazoo, Mich.
Clark Rogers Mandigo, Kansas City, Mo.
Alfred James Salisbury, Jr., Los Angeles, Cal.
James Forrest Sanborn, New York City
Edward Gwyn Sheibley, Riverside, Cal.
Hugo Conrad Soest, New York City
James Bigelow Steep, Indianapolis, Ind.
Charles Henry Stevens, Philadelphia, Pa.
Arthur John Turner, Spokane, Wash.
Joseph Johnson Vogdes, Philadelphia, Pa.
Frederick Calhoun Wyse, Columbia, S. C.

From Junior to Associate Member

Nathan Thomas Ashkins, Chicago, Ill.
Quincy Claude Ayres, Washington, D. C.
Donald McCord Baker, San Francisco, Cal.
Roy Prentice Bishop, Wilmington, N. C.
Harry William Bolin, San Francisco, Cal.
Nicholas Colas, Santiago de Cuba
Clarence Dexter Conway, Los Molinos, Cal.
Hyde Forbes, Visalia, Cal.
Edwin Ferdinand Koester, Wilmington, Del.
Eugene Frederick Mail, Robinson, Ill.
William James Henry Manning, Albany, N. Y.
John Frederick Partridge, Pittsburgh, Cal.
Roscoe Perkins, Cornwells Heights, Pa.
Eric Houghton Rhodes, Auckland, New Zealand
Harold Whitney Roberts, Houston, Tex.
William Ernest Robinson, Springfield, Mo.
John Thad Whitney, Northfield, Vt.

R. L. Humphrey, M. Am. Soc. C. E., moved that the report of the Committee on Development be taken up for consideration, and Gardner S. Williams, M. Am. Soc. C. E., moved that when the meeting adjourn, it adjourn to 2.30 in the afternoon. Mr. Rights offered an amendment that an after-meeting, or a new meeting, be held at 2.30. After considerable discussion on the question whether such an after-meeting would have authority to take action on the report, it was voted to take up the report of the Development Committee.

The Secretary read the resolutions* passed by the Board of Direction at a meeting on January 19th.

The President urged full and free discussion of the report of the Committee on Development. Mr. Humphrey offered a resolution† approving the fundamental recommendations of the Committee on Development and instructing the Board of Direction to submit the resolution and a questionnaire to the membership for letter ballot.

J. C. Ralston, M. Am. Soc. C. E., of Spokane, Wash., speaking for the members of the Society in the Pacific Northwest, strongly urged progressive action following the lines of the report of the Committee on Development. It was then moved and carried that discussion on the resolution offered by Mr. Humphrey be made a special order of business for 2.30 P. M.

The Secretary read the report of the Tellers appointed to canvass the Ballot for Officers for the ensuing year. The President announced the election of the following officers:

President, to serve one year:

ARTHUR P. DAVIS, Washington, D. C.

Vice-Presidents, to serve two years:

ROBERT A. CUMMINGS, Pittsburgh, Pa.
FRANCIS LEE STUART, New York City

Treasurer, to serve one year:

ARTHUR S. TUTTLE, New York City

Directors, to serve three years:

CARLETON GREENE, New York City
CLARENCE W. HUDSON, New York City
JOHN A. O'CONNOR, Albany, N. Y.
JOHN C. HOYT, Washington, D. C.
ANSON MARSTON, Ames, Iowa
DAVID C. HENNY, Portland, Ore.

Arthur N. Talbot and George F. Swain, Past-Presidents, Am. Soc. C. E., conducted Mr. Davis to the chair.

Mr. Davis addressed the meeting.‡

AFTERNOON SESSION.

The meeting was called to order at 2.30 P. M. in the Auditorium, President Curtis in the chair: Chas. Warren Hunt, Secretary; and present, also, about 800 members.

* See page 164.
† See page 166.
‡ See page 171.

The afternoon, as set forth in the report in full of the Annual Meeting,* was devoted to an extended discussion of the proposals in connection with the report of the Committee on Development. Mr. Humphrey's resolution, with certain amendments, was adopted.

F. J. Sprague, M. Am. Soc. C. E., addressed the meeting on behalf of a resolution† endorsing the movement to increase the pay of the commissioned and enlisted personnel of the Army, Navy, Marine Corps, Coast Guard and Public Health Services, which was carried unanimously.

F. W. Scheidenhelm advocated the appointment of a Special Committee on Water Power Development, and moved that it was the sense of the meeting that such a Special Committee should be appointed by the Board of Direction.

Motion carried.

Meeting adjourned.

Resolution Adopted at Informal Meeting During Annual Smoker, January 22d, 1920

At an informal meeting during the Annual Smoker, President Davis presiding, the following resolution was offered by C. E. Fowler, M. Am. Soc. C. E., seconded by J. C. Ralston, M. Am. Soc. C. E., and fifteen or twenty others, and unanimously adopted:

"*Whereas:* Dr. Chas. Warren Hunt, who has been our Secretary for the past 25 years, has asked to be retired from active service.

"*Be it resolved:* That we, the members of the Society assembled at the Annual Meeting, express to Dr. Hunt our concern at our loss in his active charge of the affairs of the Society, and wish him Godspeed to full recovery of his health, and for many happy years as Secretary Emeritus of the Society, which position we are pleased to know has been created for him.

"We desire further to express our great appreciation of the wonderful work he has done in building up the Society to its present large membership and high standard. The efficient organization he has built up will carry the Society to still further heights in its helpfulness to the Civil Engineers of our country and of the world.

"We further felicitate Dr. Hunt and our Board of Direction for the provision made for his future, thus preserving to the Society his services and advice for our further progress."

February 4th, 1920.—The meeting was called to order at 8.30 P. M.; Vice-President Herbert S. Crocker in the chair and acting as Secretary; and present 89 members and guests.

The minutes of the meetings of December 17th, 1919, and January 7th, 1920, were approved as printed in *Proceedings* for January, 1920.

An illustrated lecture on "Grouting Operations, Catskill Water Supply", by James F. Sanborn and M. E. Zipser, Associate Members,‡

* See pages 173 to 218.

† See page 215.

‡ Mr. Sanborn was transferred to the grade of Member on January 20th, 1920.

Am. Soc. C. E., was presented by Mr. Sanborn. Many of the engineers connected with the Board of Water Supply were present, and a full discussion followed. The following contributed to the discussion, relating experiences on this or similar work: Robert Ridgeway, J. Waldo Smith, Lazarus White, John P. Hogan, M. H. Freeman, Francis Donaldson, W. C. Briggs, A. J. Sackett, C. L. Riker, Jr., and B. A. Howes.

The Chairman announced the following deaths:

Frederick William Lehnartz, of Remscheid, Germany, elected Member, August 6th, 1879; died February 14th, 1919.

Reginald Gillon Christophers, of Auckland, New Zealand, elected Associate Member, June 24th, 1914; died October 13th, 1918.

Adjourned.

OF THE BOARD OF DIRECTION

(Abstracts)

January 19th, 1920.—The Board met at 10.10 A. M.; President Curtis in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Alvord, Clark, Coleman, Crocker, Davis, Elwell, Flinn, Hawgood, Herschel, Ketchum, Langthorn, Lewis, Metcalf, Pegram, Rights, Talbot, Tuttle, Wagner, and Wall.

Mr. Lewis, Chairman of the Finance Committee, presented a suggested Budget for 1920 which was recommended to the favorable consideration of the incoming Board.

Mr. Flinn, Chairman of the Library Committee, presented its report, which included the following:

"Several matters are still before the Committee for consideration. Among these are:

"1. Utilization of *Proceedings* Instead of *Transactions*.

At the October meeting of the Board, your Chairman reported that the Committee was considering a suggestion to omit the publication of the *Transactions* (which cost from \$20 000 to \$25 000 annually), and find some way to utilize the *Proceedings*. Thus far the Committee has not been able to offer any satisfactory solution of this problem. Due to the printers' strike, the Committee has not been able to secure the attention of the publishers to the extent necessary to work out any proposed solution.

"2. Professional Record of Members.

The October meeting of the Board referred to the Publication Committee the matter of the proposed publication of the professional record of members. This has been discussed in the Committee, with the suggestion that such a publication to be successful should be handled on a commercial basis by some outside corporation. The Committee is endeavoring to secure the views of some of the publishing houses.

"3. ABSTRACTS OF CURRENT LITERATURE.

Suggestions have been made to the Committee from time to time in regard to abstracting articles appearing in the current engineering periodicals. Your Committee has given this matter careful consideration, but has not seen its way clear to work out any satisfactory scheme of abstracting, without adding a considerable amount to the cost of publication.

"4. ADVERTISING.

It has been suggested to your Committee that the increased expenses of publication, the expense of abstracting current publications, and other general expenses, could be met by an arrangement whereby the Society accepted commercial advertising for its *Proceedings*. Your Committee has felt that this is a matter which should await the working out of the various changes in the publications suggested by the Development Committee.

"5. INDEX.

The last Index of the *Transactions* was published in 1912, and the Index should be brought up to date as soon as possible."

Mr. Rights, Chairman of the Committee to confer with a committee of the American Railway Engineering Association, reported as follows:

"At a recent meeting of the Board, a Conference Committee of three, composed of J. E. Greiner, George H. Pegram and L. D. Rights, was appointed to confer with a committee on Iron and Steel Structures, of the American Railway Engineering Association, to see if it was possible to agree on a uniform column formula, and to report back to the Board.

"The Conference Committee of the American Railway Engineering Association consisted of Prof. F. E. Turneaure, Chairman, A. W. Carpenter, W. H. Moore, and Albert Reichman.

"The two committees met at the Engineering Societies Building, New York, October 17th, 1919, and Dean Turneaure was elected Chairman and L. D. Rights Secretary of the Joint Conference.

"The committees agreed on the following propositions:

"1. That it is not desirable to have a common working stress column formula for all types of structures.

"2. That it is the sense of this Joint Conference Committee that it is desirable to have one common working stress column formula for all bridge work, designed on a static load basis. It is agreed that such a common working formula should be properly safeguarded by provisions against undue slenderness of columns or the use of over-thick material in the design.

"3. It is agreed that the Joint Conference Committee recommends that the working column formula for static loads for bridge work be

$$15\,000 \text{ lb. minus } 50\,\frac{l}{r}, \text{ truncated to } 12\,500 \text{ lb.}$$

"No agreement was reached at the Conference as to the point where the column formula should be cut off to avoid undue slenderness, but

it is the feeling of your Conference Committee that the point of cut-off should be at slenderness ratio $\frac{l}{r} = 120$."

The Special Committee appointed by the Board to study and review the report of the Committee on Development, Mr. J. W. Alvord, Chairman, presented its report in pamphlet form and the same was received and referred to the Annual Meeting of the Society.*

The Minutes of the Executive Committee Meetings held on November 13th and December 19th, 1919, were formally approved.

The acceptance of Messrs. W. M. Dawley and J. B. Jenkins as additional members of the Special Committee on Stresses in Railroad Track was reported.

In accordance with the action of the Board on October 14th, 1919, President Curtis reported his appointment of Messrs. Rudolph P. Miller, Chairman, W. K. Hatt, A. E. Lindau, W. A. Slater and S. E. Thompson to represent the Society on the Joint Committee to Formulate Special Specifications for Reinforced Concrete.

Notice was given of the appointment and acceptance of Messrs. H. E. Breed, George W. Tillson and A. B. Fletcher as a Special Committee on Highway Engineering.

Mr. Hawgood, having, at the October Meeting, been appointed Chairman of the Local Committee of Arrangements for the 1920 Annual Convention, which is scheduled to be held in District No. 11, stated he had been authorized to invite members to meet in both Houston and Los Angeles. After some discussion, including the taking of informal ballots, it was decided to hold the Convention in Houston, Tex., in the month of October.

Adjourned.

January 20th, 1920.—The Board met at 10 A. M.; President Curtis in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Alvord, Beahan, Clark, Coleman, Crocker, Davis, Elwell, Flinn, Fort, Hawgood, Herschel, Ketchum, Langthorn, Marx, Metcalf, O'Connor, Pegram, Rights, Talbot, Tuttle, Wagner and Wall.

At the request of the American Engineering Standards Committee, it was voted that this Society act as a Joint Sponsor with the American Railway Engineering Association for the organization of a Sectional Committee to deal with the subject of harmonizing American and Canadian practice in the matter of steel railway bridge specifications.

Approval was given to a proposed Constitution of New York Association of Members.

Similar action was taken regarding a Constitution of Iowa Association of Members.

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* See page 232.

Martin Schreiber was re-appointed for a three-year term on the American Engineering Standards Committee.

The term of Dr. Chas. Warren Hunt, as one of the Society's Trustees of United Engineering Society, expired on January 22d, 1920. Past-President George H. Pegram was appointed as Trustee for the ensuing term.

A. S. Baldwin was appointed to succeed Onward Bates on the Washington Award Commission, the term of the latter expiring January, 1920.

Action was taken in regard to members in arrears for dues. The resignations of 14 Members, 50 Associate Members, 1 Associate and 11 Juniors, were accepted.

Ballots for membership were canvassed, resulting in the election of 14 Members, 69 Associate Members, 15 Juniors, and the transfer of 17 Juniors to the grade of Associate Member.

Twenty-one Associate Members were transferred to the grade of Member, and 1 Associate was transferred to the grade of Associate Member.

Adjourned.

January 21st, 1920.—The Board met at 5.56 P. M., at the Headquarters of the Society, 33 West 39th Street, New York City, at the time of the Annual Meeting, as required by the Constitution (Art. VI, Sec. 7); President Davis in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Alvord, Beahan, Clark, Crocker, Cummings, Curtis, Elwell, Fort, Greene, Hawgood, Henny, Herschel, Hoyt, Hudson, Ketchum, Langthorn, Marston, Marx, Metcalf, O'Connor, Pegram, Stuart, Talbot, Tuttle, Wagner and Wall.

The Board adopted a Budget for the year 1920.

President Davis was authorized to appoint Standing Committees of the Board for the ensuing year.

The next order of business was stated to be the election of a Secretary.

Chas. Warren Hunt addressed the Board, and briefly stated that he had reluctantly concluded to ask the Board to relieve him from the duties of the office of Secretary. He explained that owing to the condition of his health, and the great pressure of work, especially during the last three years, he had arrived at the conclusion that this course was necessary, and that it was the only solution of the matter. He felt it would be to the best interests of the Society to appoint a new Secretary who would be wholly responsible to the Board; that at several times in the past he had endeavored to secure the services of an Assistant Secretary who would be able to handle the executive details in such a way as to give the Secretary time to attend only to the general business of the Society, but that all efforts in this direction

had failed, leading him to the belief that a new Secretary should now be appointed.

The Secretary then retired.

After considerable discussion and the taking of ballots to determine the policy of the Board and to elicit the individual opinions of its members, the following resolution was adopted:

"*Whereas,* Dr. Charles Warren Hunt after twenty-five years of devoted and efficient service as Secretary of the American Society of Civil Engineers, during which he has contributed to its upbuilding and prosperity to a degree which places the Society under lasting obligation to him, has indicated his desire to be relieved from active duty; and

"*Whereas,* he possesses an intimate knowledge of the business of the Society and an extensive acquaintance with its membership, which render his advice and assistance of the greatest value to the Society and its Board of Direction, the benefit of which they can ill afford to lose; therefore, be it

"*Resolved:* That Dr. Charles Warren Hunt be and is hereby appointed Secretary Emeritus of the American Society of Civil Engineers at a salary of $9 000 for the coming year, and a salary of $6 000 per annum thereafter, with such duties as the Board of Direction may assign to him."

Adjourned.

January 22nd, 1920.—The Board met at 9.30 A. M.; President Davis in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Alvord, Beahan, Clark, Crocker, Cummings, Curtis, Greene, Hawgood, Henny, Herschel, Hoyt, Hudson, Ketchum, Langthorn, Marston, Metcalf, Pegram, Stuart, Talbot, Tuttle and Wall.

President Davis announced his appointment of the Standing Committees of the Board.

At the suggestion of a Nominating Committee consisting of Messrs. Davis, Marx and Wall, there was appointed a Committee of seven to prepare and submit to the membership the necessary questionnaire covering essential recommendations of the Committee on Development, the Special Committee of the Board, and recommendations and instructions of the Annual Meeting, relating to this subject. The appointees were Messrs. A. N. Talbot, Leonard Metcalf, M. S. Ketchum, Harry Hawgood, J. C. Hoyt, R. A. Cummings and C. C. Elwell.

It was moved, seconded and carried that after canvassing the results of the questionnaire to be issued to the membership, this Committee proceed, if necessary, to formulate appropriate amendments to the Constitution, and submit the same to the Board of Direction without delay, and at all events early enough to insure their consideration at the Annual Convention.

It was moved, seconded and carried that the amount of $2 000, or so much thereof as necessary, be appropriated for the use of this Committee.

A motion was made and carried that Secretary Chas. Warren Hunt be granted leave of absence for six months owing to the condition of his health, and that his services as Secretary Emeritus begin when the successor takes office as Secretary.

The following resolution was adopted:

"*Resolved:* That the Executive Committee be empowered to designate an Acting Secretary and to employ such clerical and other assistants as may be necessary to the proper conduct of the Society's business during the absence on leave of Dr. Hunt or until a new Secretary shall have been duly elected and installed in office and to incur the necessary expense in connection therewith."*

Preliminary measures were taken for the selection of a Secretary to succeed Chas. Warren Hunt.

On motion it was ordered that the Report in Full of the Annual Meeting be put in type and sent out with the questionnaire concerning the Report of the Committee on Development.

Adjourned.

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* Conforming with this action, the Executive Committee designated Vice-President Herbert S. Crocker to act as Secretary during the leave of absence of Chas. Warren Hunt, or until the new Secretary shall have been elected by the Board of Direction.

REPORT IN FULL OF THE SIXTY-SEVENTH ANNUAL MEETING, JANUARY 21ST AND 22D, 1920

Wednesday, January 21st, 1920 (10 A. M.).—The Sixty-seventh Annual Meeting was called to order in the Auditorium of the Engineering Societies Building, 39 West 39th Street, New York City; President Fayette S. Curtis, in the chair; Charles Warren Hunt, Secretary; and present, also, about 700 members.

THE PRESIDENT.—I announce the appointment of the following tellers, Ralph H. Chambers, Kenneth Allen, Nathan C. Johnson, J. C. Meem, F. W. Perry, C. D. Pollock and Harold Tait, to canvass the ballot for officers, and their report will be ready for presentation before the close of the meeting.

The next thing in order is the report of the Board of Direction. Mr. Secretary, will you please read the report?

(The Secretary presented the Annual Report of the Board of Direction for the year ending December 31st, 1919.*)

THE SECRETARY.—In order that there should be no misunderstanding about that statement regarding reduction of interest rate on the mortgage, I will say that it costs us 1% to make the transfer. The mortgage, however, having five years to run, the resulting saving to the Society will be $6 000. The reports of the Secretary and of the Treasurer are appended.

THE PRESIDENT.—You have the report of the Board of Direction before you. What is your pleasure?

ALLEN HAZEN, M. AM. SOC. C. E.—I move that it be accepted.

(Motion seconded.)

THE PRESIDENT.—You have heard the motion, that the report of the Board of Direction be accepted. All in favor of the motion will please say "aye"; contrary "no". It is accepted.

The next is the report of the Secretary.†

THE SECRETARY.—Mr. President, the report of the Secretary is practically a statement of the receipts and disbursements of the fiscal year ending December 31st, 1919, together with the balance sheet. This balance sheet accompanying the report shows the assets of the Society, in a bookkeeping way, to be $1 280 682.30. The liabilities, in order to balance that, show that we have a surplus of $1 002 859.06.

THE PRESIDENT.—What is your pleasure as to the report of the Secretary?

G. W. KITTREDGE, M. AM. SOC. C. E.—I move that it be accepted.

(Motion seconded.)

THE PRESIDENT.—It is moved and seconded that the report be accepted. All in favor please say "aye"; contrary, "no". The report is accepted.

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* See *Proceedings*, Am. Soc. C. E., January, 1920, p. 89.

† See *Proceedings*, Am. Soc. C. E., January, 1920, p. 98.

THE PRESIDENT.—The next is the report from the Treasurer.

ARTHUR S. TUTTLE, M. AM. SOC. C. E.—Mr. President and gentlemen, the Treasurer's report for the year 1919 is as follows:

(Reads Treasurer's report.*)

CHARLES HANSEL, M. AM. SOC. C. E.—I move the report be accepted.

(Motion seconded.)

THE PRESIDENT.—You have heard the motion, gentlemen, that the report of the Treasurer be accepted. All in favor please say "aye"; contrary "no". It is accepted.

The next is the Committee to Recommend the Award of Prizes.

THE SECRETARY.—This report to the Board of Direction, dated November 28th, 1919, is as follows:

"THE BOARD OF DIRECTION,
"AMERICAN SOCIETY OF CIVIL ENGINEERS,
"33 West 39th Street,
"New York City.

"DEAR SIRS:

"The Committee appointed by President F. S. Curtis on April 25th, 1919, to recommend the award of prizes for the year 1919 begs to report as follows. The Committee has carefully considered all of the papers published in Volume 82 of the *Transactions* and recommends that Paper No. 1403, 'The Cape Cod Canal', by William Barclay Parsons, M. Am. Soc. C. E., be awarded THE NORMAN MEDAL; that Paper No. 1418, 'The Stress Measurement on the Hell Gate Bridge', by D. B. Steinman, M. Am. Soc. C. E., be awarded THE J. JAMES R. CROES MEDAL; that Paper No. 1417, 'The Hell Gate Arch Bridge', by O. H. Ammann, M. Am. Soc. C. E., be awarded THE THOMAS FITCH ROWLAND PRIZE; that Paper No. 1413, 'The Manhattan Elevated Railway Improvements', by F. W. Gardiner and S. Johannesson, Members Am. Soc. C. E., be awarded THE JAMES LAURIE PRIZE; and that Paper No. 1409 on 'Obstructions of Bridge Piers' by Floyd A. Nagler, Assoc. M. Am. Soc. C. E., be given THE COLLINGWOOD PRIZE FOR JUNIORS.

"Very truly yours,
"ALBERT S. CRANE,
"RALPH MODJESKI,
"ARSÈNE PERRILLIAT."

I have to announce, Mr. President, that the Board of Direction has awarded these prizes in accordance with the recommendations of this Committee.

THE PRESIDENT.—It is customary at this time to appoint the members of the Nominating Committee for the different districts. You will hear first the report of District No. 1. The ballots, as I understand, have been canvassed.

THE SECRETARY.—The ballots have been canvassed.

THE PRESIDENT.—The Secretary will read the report.

* See *Proceedings*, Am. Soc. C. E., January, 1920, p. 100.

The Secretary.—The final suggestions for members of the Nominating Committee were canvassed by the Committee of the Board of Direction, consisting of Messrs. Flinn, Rights and Clark, Tellers, and I will read from their report, as suggested by the President.

The report follows:

"To the Board of Direction:

"The undersigned tellers report the result of canvass of Final Suggestions for Members of the Nominating Committee in the several districts as follows:

"*District No. 1.*—	C. Raymond Hulsart	248
	William A. Howell	118
	George D. Snyder	51
	Scattering	13
	Total	430
"*District No. 2.*—	Chas. R. Gow	91
	Frank E. Winsor	53
	C. M. Spofford	24
	Scattering	8
	Total	176
"*District No. 4.*—	William L. Stevenson	50
	Robert Farnham	30
	E. B. Whitman	26
	Scattering	19
	Total	125
"*District No. 7.*—	L. P. Wolff	56
	W. C. Hoad	52
	H. E. Riggs	17
	Scattering	11
	Total	136
"*District No. 8.*—	Dabney H. Maury	79
	W. W. De Berard	25
	D. J. Brumley	25
	Scattering	17
	Total	146
"*District No. 9.*—	A. O. Cunningham	70
	Chas. H. Miller	20
	Baxter L. Brown	17
	Scattering	6
	Total	113

"*District No. 12.*—J. C. Stevens		34
	A. J. Wiley	19
	D. C. Henny*	7
	Joseph Jacobs	2
	Scattering	7
	Total	69

"Respectfully submitted,

"Alfred D. Flinn,
"Lewis D. Rights,
"Geo. Hallett Clark,
"*Tellers.*"

The Districts were taken up separately, and, by vote of the meeting, the following members of the Nominating Committee were appointed to serve for two years:

C. Raymond Hulsart	*Representing District No. 1*
Chas. R. Gow	" " " *2*
William L. Stevenson	" " " *4*
L. P. Wolff	" " " *7*
Dabney H. Maury	" " " *8*
A. O. Cunningham	" " " *9*
J. C. Stevens	" " " *12*

The President.—I now call for the report of the Special Committee to Codify Present Practice on the Bearing Value of Soils for Foundations, of which Mr. R. A. Cummings is Chairman. Is Mr. Cummings present?

The Secretary.—Mr. President, before Mr. Cummings starts, I have been requested to give a notice that a meeting of the Members of the Society who are United States Assistant Engineers will be held to-day at 4.30 p. m. in the Past-Presidents' Room, in this building, on the 16th floor. An endeavor has been made to notify each of these gentlemen as he came in; but possibly some one may have escaped, and I give this notice in hope that we will catch everybody.

Robert A. Cummings, M. Am. Soc. C. E.—Mr. President and Fellow Members of the Society: Your Committee on Soils has a report to present to you this year, that is somewhat of an enumeration of its activities during the war. Its work, like others, has been the product of reconstruction, and we are not yet in running gear for what might be called continuous operation. The report is somewhat voluminous, and it would take me about three hours to read it. I am sure you do not want to bear with me for that length of time. I shall simply relate one or two phases of the report, hitting the high spots, as it were.

* "Ineligible—On present Ballot for Officers."

There is one thing that impressed me while the Secretary was reading his report. In the disbursements there are two items that have reference to Special Committees. They amount to practically $8 000. Not one cent has been spent by the Soils Committee. In other words, the work of the Soils Committee has been conducted without expense to the Society. I can say, however, very frankly, that we should like to have some money. We could use about $3 000 if we had it.

You will note by running through our past reports that there has been quite a hesitation on our part in regard to reporting on laboratory methods. This was perhaps due largely to the fact that the work was new. There is no standard practice, the only exception being perhaps the Agricultural Bureau on Soils in Washington, and I have found that sometimes their methods were not applicable.

One of the difficult things in connection with this laboratory work has been the determination of the size of particles, and the degree of separation of particles; and I am privileged to present to you with this report the unanimous report of the Committee on the determination of size of grain and of degree of mixing of material, as found in soils. I hope it will produce some discussion and that we will hear from our members. We have been a sort of silent Committee in the past and we would like to stir up some noise.

In submitting this report I want to say that in starting this problem on investigation of soils, we found it practically impossible to co-ordinate the existing information. The science of the subject has been utterly neglected. We felt justified in throwing aside all that had been done in the past, and starting, as it were, anew. That has taken our time during the past six or seven years that we have been in existence.

Part of the report embodies the scientific point of view and has been prepared by J. H. Griffith, M. Am. Soc. C. E., who, as Chairman of a Sub-Committee of the Bureau of Standards, has given his time to this subject and presents this report as a sort of final report of the scientific aspect of the problem, laying down, as it were, the fundamental principles upon which further investigation and further experiment are necessary.

Dr. S. W. Stratton, Director of the U. S. Bureau of Standards, in transmitting this report, stated that it had not been presented to the Committee on Publications of the Bureau, and it was therefore necessary to omit all reference to the Bureau of Standards or the work which it has done on this subject. Mr. Griffith's report is in substance divided into four parts. He presents a working theory and hypothesis, elaborated in 49 pages of typewritten matter and about 25 tracings and drawings. In connection with this report Mr. Griffith has referred to the early work of our Soils Committee wherein an instrument was developed and put into practical use. It was tested in the field here

in New York City, tested in Pittsburgh, tested by the Bureau of Standards and others, and the fundamental idea behind it has proven its value in tests. Mr. Griffith has mentioned it. The Committee has kept it in the background, awaiting the opportunity of its final report, but it feels at this time that it is desirable to present it to you. The photograph and the drawings will fully explain it. With your approval the Committee will continue its activities during the coming year. I thank you, gentlemen.

THE PRESIDENT.—You have heard the report of the Special Committee on the Bearing Value of Soils for Foundations, presented by Mr. Cummings, the Chairman of that Committee. This report is not the final report, I understand. It is only a progress report. What is your pleasure, gentlemen, with reference to this report?

GEORGE F. SWAIN, PAST-PRESIDENT, AM. SOC. C. E.—I move that the report be accepted and the Committee continued.

(Motion seconded.)

THE PRESIDENT.—You have heard the motion, gentlemen, that the report be accepted and the Committee continued. All in favor, please say "aye"; contrary, "no". It is so voted.

I call now for the report of the Special Committee on Stresses in Railroad Track, Arthur N. Talbot, Chairman.

ARTHUR N. TALBOT, PAST-PRESIDENT, AM. SOC. C. E.—Mr. President, the Committee on Stresses in Railroad Track presents its second progress report. It may be recalled that two years ago a progress report was made covering certain phases of its work. This report covers the work done since that time. The Committee is co-operating with a similar committee of the American Railway Engineering Association, the membership of the two committees being practically the same.

Of course, the conditions which existed during the war interfered with the progress of the work of the Committee, and nothing was undertaken which would in any way affect the war activities. Even since the war closed conditions have not been favorable, since the work of the railroads, their opportunity to get equipment and ability to get men to help, have not been of the best.

I believe this report has been distributed. It includes the report of tests to determine the stresses in rail due to speed of locomotive and effect of counterbalance; tests to determine the depression in track under load; tests to find the depression of the tie and its pressure under load, so as to find the bending moments developed in the tie; and tests to determine how the pressure is distributed downward and laterally.

The report is presented under the following headings: "Tests to Determine the Effect of Speed and Counterbalance on Stresses in Rail"; "Track Depressions"; "Depression, Flexure and Bearing Pressure of Cross-Ties"; and "Transmission of Pressure in Ballast".

The Committee feels that this report contains information that will be helpful in understanding the action of rail, ties, and ballast and the effect of locomotive loads, and that it should lead to some modifications in railroad practice. The Committee is continuing its work.

Mr. President, I move that the report be received and printed in *Proceedings* and *Transactions,* and the Committee continued.

(Motion seconded.)

The President.—You have heard the motion, gentlemen. All in favor of that will please say "aye"; contrary, "no". It is a vote.

You will next hear the report of the Special Committee on the Regulation of Water Rights, F. H. Newell, Chairman. Is Mr. Newell present? Is there any member of that Committee who can report? I do not know who comprise the Committee.

A Member.—Mr. Chairman, how long has the Committee been in existence, and has it made any progress report during that time?

The President.—I do not know. I am sure I do not know when this Committee was appointed. I can look it up.

Mr. Swain.—I am quite sure that that Committee was appointed in 1913, while I was President.

A Member.—Has it made a progress report, was the rest of the question.

The President.—I do not know whether it has made any progress report or not.

Gardner S. Williams, M. Am. Soc. C. E.—Mr. President, perhaps I can throw a little light upon this question. I think the Committee was appointed about 1913, and I was originally a member of it. The report was submitted at that time. It was my opinion that the Committee should have been discharged, but certain members of the Committee desired to prolong it, and it was prolonged. I now move that it be discharged.

J. V. Davies, M. Am. Soc. C. E.—While I was in the Board of Direction we re-organized the Committee, at the express desire of the present Chairman, who was going to do the whole thing up in one year, and as nothing ever came of it, I have great pleasure in seconding Mr. Williams' motion.

The President.—You have heard the motion, gentlemen, that the Committee be discharged. I understand that that is the motion, is it not, Mr. Williams?

A Member.—I would like to move an amendment to Mr. Williams' motion, to the effect that the Committee be required to make a report before being discharged.

The President.—It is doubtful if you can make that.

The Secretary.—Mr. President, it is possible that Mr. Newell may have intended to be here, and may have been prevented by some accident of railroad travel. I know that one of our members was four

hours late last night, and did not get his dinner. That might be possible.

Clemens Herschel, Past-President, Am. Soc. C. E.—Mr. President, it seems to me that it would be a little hasty to discharge a committee without giving it a chance to say something in its own behalf. It is not customary in this Society, or in any other society that I know of, to judge people behind their backs, and I hope the motion will not prevail.

J. W. Alvord, M. Am. Soc. C. E.—As Chairman of the Committee on Special Committees, whose duty it is to prod the various committees from time to time, I might perhaps explain that the Committee on Water Rights has been addressed by the Committee on Special Committees several times during this past year, inquiring as to whether there would be a report submitted at this meeting, and only one answer was received to three inquiries. That answer was from the Chairman of the Committee to the effect that a very important decision in the Courts was being expected, and that the Committee desired to have that decision in its hands before making a report. The gist of the letter was that the Chairman desired to make a report and desired to have the Committee continued.

R. L. Humphrey, M. Am. Soc. C. E.—I would like to move as an amendment to Mr. Williams' motion, that the matter be referred to the Board of Direction to use its discretion in this matter, but that it is the sense of this meeting that by reason of the inactivity of the Committee, it should be discharged.

The President.—I think it is a matter for this meeting and not for the Board of Direction. This meeting appointed this Committee, as I understand it.

Mr. Humphrey.—My reason, Mr. President, for making that motion is that the Committee certainly ought to have its day in court, and the Committee on Special Committees can give it a hearing, and if it cannot give a more satisfactory reason why it should be continued——

The President.—If you will refer it to the Committee on Special Committees——

Mr. Humphrey.—It seems to me that Committee is a Committee of the Board of Direction, and it should go to the Board of Direction, which has supreme jurisdiction in the matter.

A. F. Chittenden, M. Am. Soc. C. E.—I would like to say a word with reference to this motion. Owing to my residence in Washington, and my duties there several years ago, I have been following quite closely for about ten years the question of water power and water power rights, and water power developments, and the struggles in Congress to get somewhere.

All this time the situation has been that every year there has been the possibility of Congress taking some action, and the States, the State Governments, and the engineers finding out where they stood,

and until they can find out where the Federal Government stands, and where the Courts stand, and the Courts are not quite clear always as to where they are going to stand until they know where the Federal Government stands, it has been impossible to get anywhere, not due to the fault of the people working on it, but because they are disappointed every year in Federal action.

I am quite sure, in this particular case, that more progress would have been made if more progress had been made in Congress. Now, this year it looks more favorable than ever before for action by Congress, and the moment that action by Congress does come, and there is quite a good chance of its coming too, then the situation will begin to clear up, and then the people who are discussing water rights will know better where they stand, and they will be in far better condition to make a report. Under the circumstances it seems to me that it is very advantageous to let the matter rest in the pigeon-hole for another year. At any rate, continue the Committee and let it rest in a pigeon-hole until it can get something to clarify the situation and clear up the matter.

Mr. Williams.—It seems to me that when this body creates a Committee, this body is entitled to information from that Committee as to what it is doing and what it proposes to do. I think the neglect of that Committee to report here that it was doing something, or nothing, is sufficient cause for its labors to be terminated. It is not only this year, but it is other years that this same condition has existed.

I can hardly conceive that the action of Congress in passing the water-power bill, which passed the Senate the other day, and has now gone to conference, can have any great bearing on water rights. It does not seem to me that it was necessary for this Committee to wait until now to report upon the subject of water rights, if it had anything to report; and in my opinion there is not much for it to say, and I think the meeting would make no mistake in authorizing the discharge of the Committee.

As I understand it, it is not a matter for the Board of Direction. I believe the Board of Direction cannot discharge that Committee, but that it has to be discharged as the result of a motion in this body.

H. C. Keith, M. Am. Soc. C. E.—I seconded the motion that the matter be referred to the Board of Direction; and I think that if it is given full power, as I understand the motion to be, that would authorize and give the members of the Board of Direction an opportunity to consider the activities or inactivities of this Committee and the reasons therefor, and to discharge it or not, as they see fit, after hearing the case. I hope that the motion to refer to the Board of Direction with power will prevail.

THE PRESIDENT.—I do not like to make any ruling, but if I rule, I should rule that the Board of Direction has nothing whatever to do with this Committee. It is a matter to be determined by this meeting.

MR. HUMPHREY.—Mr. President, it seems to me that the Board of Direction is the servant of this meeting, and if this meeting ceased to delegate its authority to the Board of Direction, the Board of Direction is duly authorized to exercise that authority. All we are asking is that instead of discharging this Committee in a haphazard way, the Committee be allowed to present its reasons to the Board of Direction as to why it should be continued; and if the Board thinks these reasons are sufficient, the Committee will be continued, and the Board will so report at the next Annual Meeting. It seems to me that that is the sane and logical course of procedure.

THE PRESIDENT.—Then you throw the responsibility of this meeting upon the Board.

MR. HUMPHREY.—Exactly so.

THE PRESIDENT.—I am not going to rule that the Board of Direction has nothing whatever to do with it. The motion is, I understand, an amendment to Mr. Williams' motion, that the matter be referred to the Board of Direction.

A MEMBER.—With power.

MR. CHITTENDEN.—I should like to make another remark, that the Chairman of this Committee, and possibly some other members of this Committee, may yet arrive. I just came in from the West on a train, and have been three days on the way. In one place we were delayed two hours, in another place four hours; and the railway men told me in some places people were delayed twelve hours in getting from the West here, so that it is quite possible that the Chairman of the Committee is still on the way.

MR. DAVIES.—That hardly excuses the Chairman of the Committee under the rule that requires he shall present his report before the end of the succeeding year; and the report should have been in the hands of the Secretary before the end of December.

THE PRESIDENT.—I do not see but that the Committee ought to have reported, but it would do no harm to continue that Committee. It would be much better to continue the Committee than to refer the matter to the Board. However, the motion is that it be referred to the Board of Direction with power. Are there any further remarks? All in favor of that will please raise their hands. All opposed—— The motion is carried.

THE SECRETARY.—The motion is to refer the matter to the Board of Direction with power.

THE PRESIDENT.—The Secretary has now some announcements to make.

The Secretary.—At a meeting of the Board of Direction held yesterday, it may be interesting to the members to know that the time and place for the next Annual Convention has been determined. The next Convention will be held at Houston, Tex., in October. The reason for the selection of the time—I do not know anything about it, but it seemed to be the opinion of the members of the Board who have been there, that you could not go there except in April or October.

The fact that the convention will not be held until October will probably facilitate the business of development—whatever action this Annual Meeting may take in the matter of development, and subsequently through the delegated authority. Perhaps the Board may have to issue questionnaires as to what the membership of the Society desires, and this undoubtedly will require quite extensive changes in the Constitution of the Society.

If the convention were held at the usual time, at the end of June, or the beginning of July, there would scarcely be time for the sending out of those questionnaires and the preparation of the amendments to the Constitution so that they might be presented to the convention for action, as required by our present Constitution. I think that was one of the reasons why the Board determined upon Houston. The other was that the district, Number 11, in which this convention is to be held this year, by a rule adopted some time ago, is a very large one. Another part of the district, Southern California, was very anxious to have this convention; but there have been several meetings of late years on the Pacific Coast, and almost no meetings in the South.

I think I have exhausted that subject, and I would like to call upon the Chairman of the Committee on Arrangements of the Annual Meeting, to make a statement in regard to the programme, which I am sure he wants to make.

L. D. Rights, M. Am. Soc. C. E.—Mr. Chairman and gentlemen, I have written out a little statement, so that I will not take too long. For to-day, the Committee has followed the suggestion of the report of the Committee on Development and has not scheduled any excursions. The afternoon will be devoted to the discussion of the report of the Committee on Development. To-morrow we go to the Port of Embarkation of the United States Army at Hoboken; from there we are to be transferred by ferry to the Navy Yard. So that we shall have a chance to see both of those places. The members will find their way to the Port of Embarkation at Gate 3. There are some four or five gates; so that I hope you will remember that it is Gate 3. We shall have some guides at the exits to the ferry and the tubes to direct you to Gate 3, about three blocks north of the exits.

Persons are admitted to the Port only on military pass, but the General has consented to accept the excursion ticket in lieu of passes. All members should arrange to provide themselves with excursion

tickets which may be obtained on the ground floor. Lack of tickets will subject the members to being held up at the gate until the ticket can be issued.

If any of you cannot devote his whole time to the excursion, you can leave just after the luncheon, go out of the gate, and take the tube back to New York; or you can leave the Navy Yard, at any time, go out of the gate and take the trolley car.

MR. HAZEN.—What is the most convenient way to get to Hoboken?

MR. RIGHTS.—That depends upon where you start from! You can take the Hudson Tube, as mentioned in the circular. That is probably the most convenient way if you are close to the Hudson Tube. You can take the Lackawanna Railway ferries. It is a very convenient place to get to. If you happen to be down town, the Hudson Tube at 30-50 Church Street, will take you to Hoboken, which is the Lackawanna Station. The Port of Embarkation is only about three blocks away.

For the steamer we have provided a piano and three jazz artists. I believe the Committee on Development said we should pay more attention to the younger members and we are going to give the younger members a chance to do something. They can help in the singing.

THE SECRETARY.—I have to announce the deaths of two of our members: WILLIAM LYON BROWNE, of Westmount, Que., Canada, who was elected a Member, January 31st, 1911, and died November 24th, 1919; and GEORGE WESTON, of Chicago, Ill., elected a Member, June 5th, 1907, and died January 8th, 1920.

For the record, Mr. President, I also wish to announce the election by the Board of Direction of 14 Members, 69 Associate Members, and 15 Juniors yesterday, making a total of 98 additions to the Society; and the transfer of 17 Juniors to the grade of Associate Member.* I can read those 115 names, if it is desired.

Mr. President, I have the report of the Tellers appointed to canvass the ballot for the election of officers, if it is your pleasure to have it read at the present time.

A MEMBER.—May I ask whether or not the report of the Development Committee is not to come up for consideration at this morning's session?

THE PRESIDENT.—I do not know. It was to come up this morning?

MR. HUMPHREY.—That was my understanding, that the report of the Development Committee was to come up this morning, and the discussion was to continue after luncheon. I move now, Mr. President, that we take up the report of the Committee on Development.

(Motion seconded.)

THE PRESIDENT.—The motion now before you is that at this time we take up the report of the Committee on Development. The question

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* See page 135.

is whether it would be wise to take it up now or later, in the afternoon, because it is going to take some time; but that is the motion. Is there any discussion on that motion?

MR. WILLIAMS.—Mr. Chairman, I would like to move that when this meeting adjourns, it adjourn to 2.30 this afternoon.

MR. HUMPHREY.—I second that motion. Mr. Williams' motion takes precedence, I believe.

THE PRESIDENT.—I cannot put but one motion at a time.

MR. WILLIAMS.—A motion to fix the time to adjourn takes precedence of every other motion including a motion to adjourn. My motion is that when we adjourn, we adjourn to 2.30 this afternoon.

MR. HUMPHREY.—I second the motion.

THE PRESIDENT.—You have heard the motion that when we adjourn, we adjourn to assemble at 2.30 this afternoon.

MR. RIGHTS.—I understand that it is not a motion to adjourn; it is a motion on adjournment. I would like to make a motion. The reason why I am interested is that I feel somewhat guilty. The Committee on Arrangements announced that at 1 P. M. a meeting of the Board of Direction would be held in the Past-Presidents' Room on the 16th floor, and that at 2.30 P. M. an adjourned meeting of the Annual Meeting would be held, and discussion continued on the report of the Committee on Development, or any other business. Now, that wording should have been "an after meeting", because if the Committee put that in as an adjourned meeting, it means that the new Board cannot meet, because the new Board takes office when this Annual Meeting adjourns. Now, I am not on the Board, but I am interested in seeing——

THE PRESIDENT.—You are still on the Board.

MR. RIGHTS.—I am on the Board and will continue to be until this meeting adjourns. So I would like to make the amendment that this meeting adjourn for lunch, and that we then hold an after-meeting or a new meeting at 2.30 P. M.

THE SECRETARY.—Mr. President, may I say a word in explanation? The business of the Society, as Mr. Williams knows, having been on the Board on several occasions, necessitates that the new Board shall meet and organize at this time. In every year for the last twenty-five, the programme has been that the Annual Meeting was held, and the business meeting was closed, and the new Board then came into existence.

The Committee on Arrangements, somewhat thoughtlessly and I think I was the guilty party as much as anybody else, knowing that there would be necessary a much longer time for discussion at this meeting than had been heretofore used for that purpose, instead of scheduling an excursion for the afternoon, scheduled a second meeting.

We forgot the fact that the only time during this programme that is available for the new Board to meet is between the first and second meetings. To overcome the legal point, it would only be necessary for

this resolution to be passed by this meeting that the Annual Meeting was closed at its adjournment so that the Board could do its work, and then in the afternoon the meeting could be taken up, and have exactly the same effect as if it were a scheduled meeting of the Annual Meeting.

There is no intention at all of closing discussion or shutting it off in any way, but if the Annual Meeting goes on, the new officers cannot come in until the Annual Meeting is declared closed; and they would not have any time to meet, and the business of the Society would suffer very much.

Mr. Humphrey.—I think that may all be very true; but the Society has had presented to it one of the most important reports that has come before it in recent years. We want a discussion of that report, but we also want this report to come before this business meeting for action; and if the adjournment of this meeting means that we can only discuss it, and not take action, then I think that is absolutely wrong; and I think the intention of Mr. Williams' motion is that this Annual Meeting may take action, if it sees fit to do so, on the recommendations of the Committee on Development. I would submit, in any event, that it is only fair that the report of this Development Committee should be presented at this morning's session of this Annual Meeting.

The President.—There is no doubt about its being presented. It should be presented, and it is going to be presented, but the question is whether it is better to have a continuous meeting with reference to that report of the Committee, rather than to have a partial meeting; split it up, adjourn, and then come together again; whether it is not better to arrange a time so that there would be no intermission with reference to the discussion of that report. That was all. That would give the Board a chance to organize and the new officers to come in.

There are quite a number of the members of the Board who live out of New York City, who are anxious to get away; and if the Board is not organized during the noon-time, or in the middle of the day, it cannot be organized.

William P. Parker, M. Am. Soc. C. E.—If we do adjourn, will that after-meeting have authority to take action on this report?

The President.—I think such a meeting could do so by resolution.

Charles D. Marx, Past-President Am. Soc. C. E.—Mr. Williams' motion is before us.

The President.—We are not ready to adjourn yet. I think the motion before the House practically is that when we adjourn, we adjourn to 2.30 this afternoon.

A Member.—Can we arrange to have the meeting recognized as a part of the meeting of this morning?

The President.—There is no doubt that we can.

Mr. Parker.—In order that the discussion may be under the régime of the newly elected officers of the Society, I move that we adjourn the

business meeting now, and that any action taken subsequently be of the same effect as if it had been taken at the Annual Meeting.

Mr. Williams.—There is only one motion that can be taken up, and that is the motion when to meet.

Mr. Humphrey.—I would like to ask that Mr. Williams' rider be put, that when we adjourn, we adjourn to meet at 2.30 in Annual Session. That is not debatable and cannot be amended.

N. C. Johnson, Assoc. M. Am. Soc. C. E.—As I heard that motion, it stated that we adjourn now. That would cut out the reception of the report. I think that was not the intention.

The President.—I do not understand that that was the motion. There is no motion to adjourn, but the motion is that when we adjourn, we adjourn to meet at a certain time. There is no motion to adjourn at present. There seems to be a difference of opinion as to whether to continue discussion now, and interrupt it by an adjournment, so that the discussion of the report of the Committee on Development this afternoon would be a continuation, instead of taking it up now, and then adjourning, and taking it up again.

B. S. Drane, M. Am. Soc. C. E.—As I understand it, the carrying of the motion made by Mr. Williams would make impossible the meeting of the new officers. Therefore, it would be necessary to defeat that motion and then you could proceed and carry out the wish of the Society that by action of this meeting, the regular Annual Meeting, authority should be given for a later meeting, not considered an adjourned meeting, under the authority of the present officers, to carry it along with the full authority of this meeting; but it seems to me that it would be necessary to defeat the motion that the afternoon meeting should be an adjourned meeting under the present officers.

Mr. Williams.—Perhaps I can clear the atmosphere. When this Annual Meeting adjourns, it adjourns, and that is the end of the Annual Meeting. This Annual Meeting is provided for in the Constitution, and it cannot adjourn itself and then have another meeting. If it adjourns as an Annual Meeting, that is the end of it; but if it adjourns until 2.30 this afternoon, it goes on as an Annual Meeting.

The question is whether the Board of Direction can organize this afternoon or this evening. It does not seem to be tremendously important—if a man has accepted a position as Director of the Society, I think he should spend a sufficient amount of time in the business of the Society to transact that business in accordance with the necessities of the case. If these Directors have arranged their business so that they cannot stay here longer than this afternoon, 1 or 2 or 3 o'clock, I think, gentlemen, that we have made a mistake in selecting our Directors.

As has already been said, we have before us the most important question that has been before this Society in years. Whether we

take it up now, this morning, and endeavor to dispose of it before noon, or before we adjourn, or whether we let other business go ahead, and take it up this afternoon, or whether we start this morning, and go on this afternoon, I do not consider particularly material. But I do consider it important and necessary that that report be considered by the Annual Meeting, and not by some adjourned appendix that is not the Annual Meeting, and cannot be the Annual Meeting, if the Annual Meeting adjourns as such.

A. N. Talbot, Past-President, Am. Soc. C. E.—Mr. Chairman, I quite agree with Mr. Williams that when this meeting adjourns as an Annual Meeting that will be the end of the Annual Meeting and it cannot delegate any power to an after-meeting. If discussion is to be had on this report as a report to the Annual Meeting, it should be done during the time the Annual Meeting is in session.

So far as the meeting of the Board of Direction is concerned, I wish to make a suggestion, which I have made before, that at this time the report of the canvass of the ballot be made, the officers be declared elected; that they then, if they wish, hold a meeting during the recess, and take whatever action they desire—which is not legal, but that to save time they may, later, when they do come into authority, approve the acts that they have performed. It seems to me that would get us out of the difficulty.

M. O. Leighton, M. Am. Soc. C. E.—I want to call attention to the fact that during this discussion we have occupied enough time to have elected our officers and gone a long way in the consideration of the Development Committee's report. I therefore ask unanimous consent that the announcements of the Tellers be given to the meeting and voted on, and thereafter we proceed to the discussion of the Development Committee's report. I think that will take about five minutes.

Mr. Parker.—We are all very anxious to hear that information. I think the delay has been caused by the fault of no one. If you will put the motion to fix the time——

The President.—The motion is certainly in order and the discussion is in order. If any one would like to discuss the matter, I do not see why they should not have an opportunity, and as the motion now is—no matter regarding the Board of Direction, whether it meets now or later—if it should be carried, the new President cannot appoint his committees until the final adjournment of the meeting. The question is that when we adjourn we adjourn to meet at 2.30 this afternoon. All in favor of that please say "aye".

Mr. Humphrey.—I would like to raise a point of order. I do not think the word "adjourn" is in order. We can recess.

The President.—I think it is the same thing. I do not think it makes any difference whether you call it adjournment or recess.

A MEMBER.—I move we hear the report of the Tellers and immediately thereafter go to the consideration of the Development Committee's report.

THE PRESIDENT.—I am going to present that now. The Secretary will now read the report of the Tellers.

MR. HUMPHREY.—I move that that be deferred until we get ready to adjourn, about 1 o'clock.

THE PRESIDENT.—I think we will be ready to adjourn about the time we get through with this; I think very likely we will all be hungry.

MR. HUMPHREY.—I dislike to object to the procedure; but the luncheon hour is an hour away. Instead of wasting time on continual motions, we might take up the report of the Development Committee——

THE PRESIDENT.—If you will make the motion.

MR. HUMPHREY.—I have made the motion, and it has been seconded by the gentleman over here.

THE PRESIDENT.—That we take up the report of the Development Committee. That is the motion. All in favor please say "aye"; contrary, "no". I am not sure. Therefore, I will ask those who are in favor to raise their right hands.

A MEMBER.—In favor of what?

THE PRESIDENT.—The motion before the house.

A MEMBER.—What is it?

THE PRESIDENT.—The motion is that we immediately take up the report of the Committee on Development.

A MEMBER.—My friend on the right made a motion previous to that, that we proceed to the election of officers.

THE PRESIDENT.—The question before the house is now that we take up for discussion the report of the Development Committee.

A MEMBER.—Before we adjourn?

THE PRESIDENT.—I do not think there is any necessity for discussion about it. We have voted on it, but the Chair could not decide by a yea and nay vote. Those in favor of the motion will please raise their hands.

THE SECRETARY.—187.

THE PRESIDENT.—All opposed, raise their hands.

THE SECRETARY.—There are only 42.

THE PRESIDENT.—The motion is carried that we immediately take up the matter of the report of the Development Committee.

THE SECRETARY.—The report of the Development Committee was issued to the membership some time ago, under date of November 15th, 1919. I assume that there will be no necessity for reading that report unless it is called for. As stated in the letter transmitting that report, the Board of Direction, upon receiving the report of this Committee on Development, appointed a Committee of five members of the Board of

Direction to study and review the report of the Committee on Development, and present a report as soon as practicable for distribution to the members of this Board by letter, so that the Board could consider the whole matter at its next regular meeting.

The next regular meeting of the Board was held on Monday and Tuesday of this week, yesterday and the day before. At that meeting the report of the Sub-committee of the Board consisting of Messrs. John W. Alvord, Charles D. Marx, Herbert S. Crocker, Samuel T. Wagner and John A. O'Connor, was received by the Board and ordered distributed to the membership. I assume that every member here has a copy of that report. They were downstairs for distribution on registration of each member. The Board presents that report for the consideration of this Annual Meeting.

At the meeting of the Board of Direction on January 19th, 1920, the following resolutions were adopted:

"*Whereas:* The Board of Direction is in sympathy with the objects sought in the report of its Development Committee, and with the view of its Special Committee already approved as an alternative by the Development Committee, that Engineering Council should be made more representative of the Engineering and allied technical professions, and that its functions should be broadened and more liberally supported financially; and

"*Whereas:* It is desirable that the ma n questions involved should be submitted to the membership of the Society for action by letter ballot as soon as possible;

"*Be it Resolved:* That the Board of Direction recommends to the incoming Board of Direction that a Committee of seven be appointed to prepare and submit to the membership forthwith necessary questionnaire or questionnaires covering the essential recommendations of its Development Committee and of its Special Committee, and the recommendations and instructions of the Annual Meeting of January, 1920, relating to this subject, and that it make appropriation for the necessary expenditures of the Committee.

"*Be it Further Resolved:* That a Committee of three be appointed by the present Board of Direction to present nominations for members of this Committee of seven for submission to the incoming Board of Direction at its meeting of Wednesday, January 21st, 1920."

and it was also

"*Resolved:* That the Board of Direction, in order to learn the sense of the members present, submit to the Annual Meeting the following questions relative to technical activities and internal relations of the Society:

"1. Shall the Annual Meetings be supplemented by the addition of a Spring and Fall Meeting? (See Division A, Section 1.)

"2. Shall the monthly *Proceedings* be extended to include abstracts of important engineering articles? (See Division A, Section 1.)

"3. Shall local sections be created to embrace the entire membership of the Society? (See Division B, Section 1, a, b, c.)

"4. Shall the Directors in each geographical district be nominated and elected by vote of the Corporate Members resident therein? (See Division B, Section 1, e, f, g.)

"5. Shall a portion of the Society dues be allotted to local sections (See Division B, Section 1, i.)

"6. Shall the officers at large be nominated by representatives of local sections in an annual conference? (See Division B, Section 1.)

"7. Shall the present grades and requirements for membership be revised? (See Division B, Section 2.)

"8. Shall the Board of Direction arrange for the establishment of Civil Engineering student membership? (See Division B, Section 4.)"

In addition to that, the Board also ordered presented for the consideration of this meeting the questions submitted in the report of its Special Committee. Those questions were:

"1. Shall the American Society of Civil Engineers use its power and influence to bring together for welfare purposes the Engineering and related technical professions of America?

"2. If so, shall it assent to the formation of a new and somewhat unrestricted organization, as proposed by the Development Committee?

"3. Or, shall it develop and broaden the basis of the present Engineering Council, as well as make it more representative than at present, all as newly proposed herein?

"4. Shall the dues of non-resident corporate members be raised not less than $5.00 nor more than $10.00 per annum for this purpose?"

This action of the Board, I would like to make clear, was to refer these questions to the Annual Meeting, so that they should concretely come before the Annual Meeting, and the resolution for the proposed appointment of the Committee to take charge of the issue of questionnaires was intended to facilitate and expedite the work of getting out the necessary questionnaires in order to get results as soon as possible, after the discussion was fought out at the Annual Meeting as to what the Annual Meeting wanted to send out. I believe that is a correct statement.

The President.—Gentlemen, of course we have the report of the Development Committee. The Board has tried to separate certain questions, which have to do with that report, so as to have them sent out to the Members of the Society, to get replies before the next Annual Meeting, so that they could be acted upon. The whole thing is before you. It is a question whether you desire to take up these questions first, as presented by the Board, to take any action upon them as they are presented for your consideration, or whether you want to take up some other business. I am going to leave the whole thing entirely to you, to allow you to discuss it, and take your full time in doing it. We are not trying to fence or save any time, because I think it is an important matter, and I think every one ought to have a fair opportunity to express his own views.

Mr. Humphrey.—It seems to me that there are fundamental questions, which this Annual Meeting should decide, and then send out to the membership of this Society for action. I believe we will not make any progress by debating details. There are certain great problems that the Society is confronted with that I think we should now act upon. I feel that we ought to have the matter in some tangible shape and it is for the purpose of bringing the matter into tangible shape that I am now speaking.

There has been some criticism of the report of the Committee on Development, on the ground that it exceeded its authority. I think the members of the Society generally, and some of the members of the Board of Direction, are not aware of the resolutions and the precept which the latter instructed the President of the Society to prepare, which served as instructions to the Committee on Development, and under which it acted in the scope of its work.

I want at this time to introduce a resolution, and I make this explanatory statement as to the resolution of the Board of Direction and of the precept of the President, in order that we may have in this document all the information and authority under which the Committee on Development acted. I, therefore, offer the following resolution:

Whereas: The Board of Direction of this Society in the preamble of its resolutions adopted June 18, 1918, states in part as follows:

"Sociological and economic conditions are in a state of flux and are leading to new alignments of the elements of society.

"These new conditions are affecting deeply the profession of engineering in its services to society, in its varied relationships to communities and nations, and in its internal organizations.

"A broad survey of the functions and purposes of the American Society of Civil Engineers is needed in order that an intelligent and effective readjustment may be accomplished so that the Society may take its proper place in the larger sphere of influence and usefulness now opening to the profession.* * *

"The Constitution should be revised only after securing the views of the membership of the Society as to what its purposes and activities should be and as to the instrumentalities through which these purposes and activities should be carried out.

"Any changes in organization must take into account all the conditions above indicated, and also the relationship of the American Society of Civil Engineers to other engineering organizations and to the public."

which resolutions authorized the creation of a Committee on Development; and in the precept, which it authorized the President of the Society to prepare, the work of this Committee was outlined as follows:

"The resolutions contemplate an examination of present-day conditions and an outlook into the future. They involve considering the

changing social and industrial relations of the times and the opportunities and responsibilities which devolve upon the Society and its membership. The relations of the Society to other societies and to the profession generally are also included. The outcome of the work of the Committee may be modifications in the activities, functions, and methods of work, or in the emphasis in these matters, and possibly the addition of new ones.* * * *

"It is expected that the Committee will report definite recommendations in the field of its work and these recommendations may include proposals of fundamental changes which may involve amendment of the Constitution of the Society."

And Whereas: The Committee on Development presented to the Board of Direction at its meeting on October 14th, 1919, a comprehensive report, in which was included the report of the Joint Conference Committee representing the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers, and the American Institure of Electrical Engineers, containing fundamental recommendations for the development of the Society along lines intended to so broaden its activities as to enable it to become a National force, in co-operation with other engineering and allied technical associations, in economic, industrial and civic affairs.

Therefore Be it Resolved: That the Sixty-seventh Annual Meeting of the American Society of Civil Engineers hereby approves the fundamental recommendations contained in the report of its Committee on Development, and

Be it Further Resolved: That the Board of Direction be and is hereby directed to submit this preamble and these resolutions and the following questionnaire in a letter-ballot to the corporate members of the Society on or before February 9th, 1920, which ballot shall be canvassed not earlier than March 1st, or later than March 16th, 1920.

A.—External Relations.

1. Shall the American Society of Civil Engineers "adopt the principle of becoming an active National force in economic, industrial and civic affairs"? (Division C, page 10.)*

2. Shall the Society actively co-operate with other engineering and allied technical associations in promoting the welfare of the Engineering Profession? (Division C, pages 10-19.)*

3. Shall the Society for the purposes set forth in Questions 1 and 2 actively co-operate in the creation of the comprehensive organization as outlined in the Joint Conference Committee Report? (Division C, pages 10-19.)*

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* See Report of the Committee on Development to the Board of Direction of the American Society of Civil Engineers.

B.—INTERNAL RELATIONS.

1. Shall the recommendations of the Committee on Development as to technical activities be adopted? (Division A, Sections 1-5, pages 4-6.)*

2. Shall local sections be created to embrace the entire membership of the Society? (Division B, Section 1, a, b, c, and h, page 6.)*

3. Shall the Directors in each geographical district be nominated and elected by vote of the Corporate Members resident therein? (Division B, Section 1, e, f and g, page 6.)*

4. Shall a portion of the Society dues be allotted to local sections? (Division B, Section 1, i, page 6.)*

5. Shall the present Nominating Committee be abolished and candidates for the office of President, two Vice-Presidents and Treasurer be nominated by representatives of local sections in annual conference? (Division B, Section 1, j and k, pages 6-7.)*

6. Shall the dues of all Non-resident Members above the grade of Junior be increased to provide for greater activities of the Society, but not to exceed $5.00 per annum?

I present that resolution, Mr. President, for the purpose of crystallizing debate, and for getting immediate action in the form of a motion.

(Motion seconded.)

J. C. RALSTON, M. AM. SOC. C. E.—I come from the State of Washington and speak for the engineers and their various chapters in the Pacific Northwest. I desire to second that motion. The engineers of the Pacific Northwest, and I am sure a large majority throughout the country, are looking to this Annual Meeting to submit a questionnaire, reaching to the fundamentals, fairly and comprehensively, as developed by the Development Committee.

We are seeing it through this unique and remarkable situation: We see scores of young engineers and scores of prospective young engineers trooping by the doors of our respective chapters, with sneers on their faces, rushing into the meretricious arms of the American Association of Engineers. We see various civil bodies, industrial, technical, commercial, and other technical bodies, which have heretofore been more or less inert—some of them may have been even emasculated—but we suddenly see them rising to a new vision of utility.

We take the opportunity, therefore, of warning, or urging that the American Society of Civil Engineers also respond to the vision of utility, and rise, if you please, above the inertia of pre-war inactivity to the mountain tops of post-war accomplishment.

MR. WILLIAMS.—It is now after 12.30, and I move that this resolution be made the special order for 2.30 this afternoon.

* See Report of the Committee on Development to the Board of Direction of the American Society of Civil Engineers.

MR. HANSEL.—I second the motion.

THE PRESIDENT.—You have heard the motion, which is that we adjourn——

(Cries of "no.")

MR. WILLIAMS.—That it be made a special order.

THE PRESIDENT.—The motion is that this motion be made a special order on our re-convening this afternoon.

MR. WILLIAMS.—Be made a special order at 2.30 this afternoon.

THE PRESIDENT.—I think it would be anyway without the motion.

S. N. CASTLE, M. AM. SOC. C. E.—It seems to me that Mr. Humphrey's resolution goes, in good old fashioned English, to the "guts" of the whole matter. I, therefore, definitely oppose the postponement of this resolution to any special order. Let us take this thing up and discuss it now. Do not be finicky about our speech. Go right to the heart of the matter.

THE PRESIDENT.—There is no amendment to the motion; therefore, I shall have to put the motion.

J. H. GRANBERY, M. AM. SOC. C. E.—I should like to amend Mr. Humphrey's motion to the extent that the statement of approval of the findings of the Development Committee be postponed until such time as the Society has had an opportunity to pass upon the subject by discussion.

MR. WILLIAMS.—I rise to a point of order. The motion to make this a special order at a special time is to be disposed of.

THE PRESIDENT.—I think so. Are you ready for the question? All in favor please say "aye"—I do not think I need to put the other—contrary, "no". It is to be a special order to be taken up immediately on the convening of this convention at 2.30 P. M., but the whole matter is still open for discussion at the present time.

MR. LEIGHTON.—I move we receive the report of the Tellers as to the new officers.

(Motion seconded.)

THE PRESIDENT.—The motion is that before we adjourn we take up the report of the Tellers. If there is no objection to that, we will so take up the Tellers' report. There being none, will you make the report, Mr. Secretary?

(The Secretary read the Report of the Tellers, as follows:)

33 West 39th Street, New York, N. Y.,
January 21, 1920.

"TO THE SIXTY-SEVENTH ANNUAL MEETING,
AMERICAN SOCIETY OF CIVIL ENGINEERS:

"The Tellers appointed to canvass the ballots for Officers of the Society for 1920 report as follows:

"Total number of ballots received			2 074
	Ballots without signature	17	
	" stamped, not signed	8	
	" from members in arrears of dues	6	
	Total number not entitled to vote		31
	Ballots canvassed		2 043
	Defective		2
"*For President:*			
	Arthur Powell Davis		2 029
	Scattering		11
"*For Vice-Presidents:*			
	Robert August Cummings		2 023
	Francis Lee Stuart		2 018
	Scattering		11
"*For Treasurer:*			
	Arthur Smith Tuttle		2 040
	Scattering		1
"*For Directors:*			
District No. 1	Carleton Greene		1 985
	Clarence Walter Hudson		1 972
	Scattering		8
District No. 3	John Adam O'Connor		1 976
	Scattering		5
District No. 5	John Clayton Hoyt		1 974
	Scattering		3
District No. 7	Anson Marston		1 979
	Scattering		9
District No. 12	David Christiaan Henny		1 982
	Scattering		6

RALPH H. CHAMBERS,
KENNETH ALLEN,
J. C. MEEM,
C. D. POLLOCK,
HAROLD TAIT,
F. W. PERRY,
NATHAN C. JOHNSON,
"Tellers."

THE PRESIDENT.—I now declare the following elected:

President, Arthur Powell Davis.

Vice-President, Robert Augustus Cummings and Francis Lee Stuart.

Treasurer, Arthur Smith Tuttle.

Directors: District No. 1, Carleton Greene and Clarence Walter Hudson; District No. 3, John Adam O'Connor; District No. 5, John Clayton Hoyt; District No. 7, Anson Marston; District No. 12, David Christiaan Henny.

If there is no objection we will proceed to new business. That is next in order. If there is no new business to come before the meeting——

THE SECRETARY.—Mr. President, if it is possible for the Secretary to make a motion, I would move you, sir, that our newly elected President be presented to the Meeting at this time.

(Motion seconded.)

THE PRESIDENT.—I think that is customary and should be done, but on account of its not being the end of the Annual Meeting, I do not know whether it would be the proper thing to do it now or later, but if there is no objection, it may be done now.

MR. WILLIAMS.—There can be no objection that I can see to presenting the newly elected President to the Meeting. I think you cannot turn over the business of the Meeting to him, but you may let him make a speech, and we would be delighted to hear him.

THE PRESIDENT.—That gives me the greatest pleasure that I have had for a long time, to introduce the new president, and I am going to ask Professor Talbot and Professor Swain if they will escort the new president to the platform.

Allow me to present the new President, Mr. Davis.

MR. DAVIS.—Mr. President and gentlemen of the American Society of Civil Engineers, I am profoundly grateful for the great honor which you have done me; and find it impossible to explain, under any reasonable hypothesis, when I reflect upon the eminent men who have occupied this position, and the great importance of the position itself. I am no less impressed with the responsibilities that are placed upon the Board of Direction for the following year and with a sense of relief that the President's term is as short as one year, so that you can get somebody who will do the job better, if it is not finished, as it will not be, by the time the year is up.

I feel very grateful for the complimentary reference of the gentleman who explained that you wanted a speech from me. It is a great act of charity and of compassion to let a man emit a bottled-up speech. But I have no speech bottled-up, and I know you are very busy. I know that this day has more in it than we have time to accomplish. We have the most important things, as has already been stated, to consider today, that we have considered for years; and, therefore, with

a statement of my sympathy with the progressive movement that is well nigh unanimous in this Society, and the hope that those of us, among whom I expect to be numbered, who do not accomplish all that we hope to do in all details, will accept the result with good grace, when we have said all that we have to say and have voted, and have expressed our opinion, and the thing is finally decided definitely, we will all get in and work for a new birth of activity on the part of this Society in filling the niche, which has presented itself here, and which it is our duty to get in and fill, if it is ever to be filled with the efficiency that it should be.

The history of this Society is a great one; its growth has been large and constant; its standards are high; but looking back over the years, we realize if we had known the things we now know, its accomplishments could have been greater. Due to the conservatism of this Society, in taking up new ideas or advancing into new fields, there have been other societies organized to occupy those fields, and they have accomplished a great work for which I have nothing but praise. But I feel the conviction that it could have been accomplished before, with less effort and less expenditure by the engineering profession, if this Society had occupied those fields and accomplished those things itself.

Now, it should not be and I hope it will not be our effort to elbow any of those societies out of the functions that they are fulfilling, but there are other things presenting themselves which this Society should do, and there is no other organization or organizations which can take the place of this one in its standing before the public and before the Engineering Profession and before the world at large unless it takes over our membership *in toto*. No other society can occupy that place, and, consequently no other society can do the work that is laid out before us. If we fail, that work will necessarily fail; but it will not fail unless the Society goes to pieces and passes out of existence, so that some other society can come in to take its place.

There will be more to be said in the discussion this afternoon, and it is possible—very likely—that I will take part in it. It is not my function to preside this afternoon, as I am not yet President of the Society. The constitution requires that the newly elected officers take office at the end of the Annual Meeting; and by the action taken this morning, that Annual Meeting is not ended and cannot end with this recess that is about to occur.

The suggestion made by Mr. Talbot that the Board of Direction meet immediately after this meeting, accomplish what it can in an informal way, and afterward confirm that, does not especially appeal to me. It may be, and probably will be, that very important matters from a legal standpoint will be presented to the Board of Direction at

its first meeting; and an informal meeting, afterward confirmed by some kind of resolution, might be open to question.

We can accomplish just as much in a twenty minutes or an hour or two hours' session after five o'clock this evening, as we can by a shorter or a similar length of session between 1 and 2:30 P. M. So that no time will be gained by meeting in an informal way, and we shall cut out the necessary circumlocution of making that legal which is not legal, afterward. The question whether we can do such a thing or not might possibly arise. The argument has been made that we can transact our business while other people are eating lunch. We can transact our business while other people are eating dinner this evening as well. So that unless some member of the Board of Direction makes objection I shall now call a meeting of the new Board of Direction to be held immediately at the end of the Annual Meeting, as contemplated and specifically required in the constitution, that is, as soon as it can be done under the constitution. Unless there is objection, that will be the understanding.

If there is no objection, we will meet then at the close of this Annual Meeting immediately. Then if it is meal time, we can adjourn to some later hour, possibly, or do as we please in that regard. Is there objection? I hear none. Therefore, gentlemen, I thank you profoundly again, and will do my utmost during the coming year to serve you in a manner that will be acceptable and to the ultimate benefit of this Society. I thank you.

A MEMBER.—I move we adjourn.

THE PRESIDENT.—I hear somebody say something about adjournment; that suits me too.

THE SECRETARY.—Mr. President, before we adjourn, a member of the Committee on Arrangements, who is looking after this luncheon—which I think some of us may get—wishes to make an announcement—Mr. Gilman.

CHARLES GILMAN, ASSOC. M. AM. SOC. C. E.—Gentlemen, the luncheon will be served at 1 o'clock in the Meeting Room on the 5th floor. Seats have been arranged longitudinally in the rooms, and you are requested to take those seats as far as they will go. The waiters will pass through the aisles, and if you will not congest the aisles, your luncheon will be successfully served.

A MEMBER.—I move we recess until 2.30 P. M.

(Motion seconded.)

THE PRESIDENT.—The motion is made that we adjourn to 2.30 this afternoon. All in favor, say "aye"; contrary, "no". Carried.

Recessed to 2.30 P. M.

AFTERNOON SESSION.

The meeting was called to order at 2.30 P. M. President Fayette S. Curtis, in the chair; Chas. Warren Hunt, Secretary; and present, also, about 800 members.

THE PRESIDENT.—The matter before the meeting is the resolution presented by Mr. Humphrey; that is the first thing to be considered. That matter is open for discussion to anybody who desires to discuss it.

MR. RIGHTS.—Mr. Chairman, I ask that the resolution be read again.

(The Secretary read Mr. Humphrey's resolution as presented at the morning session.)

THE SECRETARY.—I have omitted the references which are here.

MR. HUMPHREY.—Mr. President, I would like to suggest, in order to expedite the debate on this resolution, that we pass the preamble temporarily and take up the questionnaire, question by question, and approve of it; and unless there is objection, I would suggest that we take up question No. 1, under Sub-division A, and I formally move the approval of it.

MR. HANSEL.—I second the motion.

THE PRESIDENT.—Is there any objection to that?

ALEX. C. HUMPHREYS, M. AM. SOC. C. E.—I am wondering whether in an important matter of this kind, we want to expedite the discussion too much. Do not let us have anything railroaded. It is too serious a matter for expedition.

THE PRESIDENT.—Whether that would expedite the matter or not, I do not know, but the suggestion is made that we take each question up separately for discussion and action.

MR. HUMPHREYS.—I am not objecting to the course, I am simply throwing a word of warning as to the general proposition.

A MEMBER.—Mr. Chairman, will you read that question so that we will know what we are talking about.

MR. HUMPHREY.—In order to concentrate on one item at a time I repeat my suggestion that we take up for action the first question on Sub-division A.

THE PRESIDENT.—That is what I understood. This relates to external relations, and the first question is, "Shall the American Society of Civil Engineers adopt the principle of becoming an active National force in economic, industrial and civic affairs?"

A MEMBER.—I move its adoption.

(Motion seconded.)

THE PRESIDENT.—It is open for discussion.

W. M. BLACK, M. AM. SOC. C. E.—I have been out of touch with the Society for a number of years.

THE SECRETARY.—Will you not come forward?

GEN. BLACK.—What I have to say will take but a moment. I would like to know what these things mean. I got the report of the Committee on Development this morning. I see the questionnaires, but do they mean anything? In what way are we to be an active force in economics? Surely we are not to go into politics. I would like to know, it is very indefinite about the whole matter. A very eloquent gentleman from the Northwest addressed us this morning about the

mountain tops, but I could not find out what we were going to do when we got there. And so all the way through. These resolutions seem to be so very general that we might as well adopt a resolution that the earth is round and the heavens are big. It seems to me we are not specific enough. Let us get down a little bit to brass tacks and say what we propose to do.

We have always been active in outside affairs to a certain extent. Now, it is proposed to extend that activity. How? In what manner, to what end? I am asking for information, and I hope that in the discussion on this resolution, some one will kindly say something specific that we may know what we are voting for.

The President.—I will ask Mr. Humphrey if he can give us any more information on the questionnaire.

Mr. Ralston.—Mr. Chairman, if the previous speaker had had the rare good fortune and the time to have read the report of the Committee on Development, he probably would have seen the significance of all the questions in this questionnaire, and particularly Question No. 1 which is, "Shall the American Society of Civil Engineers adopt the principle of becoming an active National force in economic, industrial and civic affairs?" or, by inference, shall it remain inert?

Now, by reading through the whole report, and I take it the large majority who are here present have read the whole report, you will find that it suggests in its modest way, how far in the matter of external relations the American Society of Civil Engineers shall go and how much farther than at present it may go with respect to its internal relations. So that I venture to suggest and submit that the report itself speaks for the entire concept and is a concentrated effort on the part at least of the Development Committee to explain to the membership about how, in a general way, the Society may become a National force and not remain wholly, or largely, as it has in the past, a purely technical organization.

S. Whinery, M. Am. Soc. C. E.—Mr. President, I rise to a point of order. At the meeting this morning a general programme prepared by the Board of Direction was submitted to the meeting, evidently with the request that it be acted upon by this meeting. It may cover substantially the same ground as this resolution: but, as a matter of fact, in parliamentary procedure, it is the duty of this meeting to consider those recommendations in preference to any other business before the meeting.

Mr. Parker.—If you will remember the action this morning, this body made a special Order of Business at this time, which takes precedence over instructions from the Board.

The President.—There cannot be anything else considered until this is fully considered and then we can take up, if it is the pleasure of the meeting, the report of the Board of Direction, or anything else;

but I doubt if you can take up anything else at present, except what is before you now.

W. H. Hoyt, M. Am. Soc. C. E.—It seems to me that it is a little out of order to take up each individual question submitted in this questionnaire. The resolution before this meeting at the present time is a direction *in toto* to the Board to submit the resolution and this questionnaire to the membership of the Society for individual vote. I do not see that we have the authority, although we may discuss the matter. As the resolution stands at present, it is a resolution to refer to the membership the questionnaire, as submitted, for the individual vote of the Society.

We believe, the Association of the Members of the American Society of Civil Engineers at Duluth, believes that this Committee on Development was well appointed by the Board of Direction. The instructions for the Committee and the foreword by Past-President Talbot, submitting those instructions, were to the point, and gave the Committee almost unlimited scope.

This report has been printed and submitted to the membership, but we have not yet had an opportunity to express an individual opinion upon the various matters. There are no doubt many things in that report that are more or less minor, and were inserted as suggestions to the Board; but there are certain fundamental principles upon which the membership of the Society should be given an opportunity to express their individual opinions; and as I understand it, the motion now before this meeting is to submit such questions to the Society.

I understand, from the officers of the Society who have been quoted to me, at least, that when questions of this kind have been submitted to the popular vote of the Society, they have been almost always successfully solved. That is, what we are asking today is the submission to the Society of these questions on which members may have an opportunity to express their individual opinion. I do not see how we can take up the individual discussion of the questionnaire.

The President.—I shall have to state to you that the gentleman who offered the resolution thought it would be a wise thing to take up each question separately and asked the privilege to do it, and there was no objection raised by any member here, and therefore, we are proceeding in that way. I do not see any reason why that is not the proper procedure. I gave every one an opportunity to object to this and no one objected.

B. A. Howes, Assoc. M. Am. Soc. C. E.—It often happens that a most explicit legal document is not thoroughly understood by the men who receive it, especially if they are not versed in legal phraseology. So it seems to me that possibly, in order to expedite this matter, a general explanation by men who are versed in what it aims to do would help us along in this meeting. If it is in order I would like

to propose an amendment to the motion to the effect that time be allotted for general discussion before taking up the items.

THE PRESIDENT.—I think perhaps you are out of order. This thing has been passed upon.

MR. HUMPHREYS.—I second the amendment.

MR. HUMPHREY.—I hope that that amendment will not prevail. I think we have wasted enough time this morning on trivial matters, and to waste half an hour on this thing and then take the items up separately would be a waste of time. We are taking up these items separately, and during the discussion the whole matter will be brought out, and all the information will be obtained. When we have discussed all the questions involved, we will then be in a position to see whether we want to decide them. It seems to me, on this matter, that if we waited for ten years for some of the members of this Society to read that report of the Development Committee, they would not read it, or understand it.

MR. HOWES.—I move an amendment to the effect that time be allotted for general discussion of this whole subject before the items are taken up in detail.

MR. HUMPHREYS.—I second it.

THE PRESIDENT.—There is a motion before the house. I think you all understand it. All in favor of it please say "aye"; contrary "no". I judge from the noise that it was defeated.

We will proceed to take up the questions one by one. I think we should give plenty of time to debate these different questions, as they come up. I do not think we ought to cut out discussion on these items, and I am going to allow all the liberty that I can on these different questions as they come up.

MR. RIGHTS.—I would like to ask as a point of information: suppose we pass the first item, do I understand that this carries with it the general resolution that it must be submitted by the Board of Direction?

MR. HUMPHREY.—No; that is not the intent. It means that the meeting has approved the form of the question.

A. P. DAVIS, M. AM. SOC. C. E.—If it is adopted in this form the Board of Direction, nor anybody else, would have no right to change a letter in it.

MR. HUMPHREYS.—The answer that was just given by the incoming President, that if this is passed the Directors will have no right or opportunity to change a word, is most significant. I protest that in an important matter of this kind we do not want to hamper the Directors in any way in their efforts to bring out all the information they can from the members. Let them send this question out if they like, but do not by implication leave it so that the Directors cannot amplify the questionnaire in any way that their judgment dictates.

Let me say, in answer to Mr. Humphrey, that the fact that he has studied this proposition—I have studied it also—is by no means ground for reflection on many members here that they are not able to answer the questions that may come up, without full discussion, and we want to avoid anything like railroading.

Now, a former associate on the Board has asked a question, he is a most intelligent man, and it needs an answer. He happens to have the courage to ask that question. There are probably dozens of men who have questions that they would like to ask but they do not want to get up and expose their ignorance. In the first little society of which I was a member, I sat and listened for ten years to the "bunk" that was gotten off.

Mr. Hansel.—I think the first question is the easiest answered. It was the outcome of our study of the duty that was upon us all. The Committee on Development had its first conference in Chicago. It was our endeavor to find out just what we were expected to do; and I think if you will take the question that you are asked to consider now, it will be the Committee's understanding of the intent of the resolution and the precept of Past-President Talbot. If we had not decided that that was it, we would not have known that we had anything to do, and having decided that that was the thing that we were entitled to do, that the Society did believe that it should go out and do its share in the world's work, we followed it up in great detail, considering the lack of time, and, therefore, it is, I think, the interpretation of the orders which we received.

J. N. Chester, M. Am. Soc. C. E.—The impression seemed to prevail in some recent remarks that have been made, that by approving this Question No. 1, as the motion is made, that we limit or curtail the Board of Direction in amplifying the questionnaire in any way. Not so. The Board of Direction is only bound to send these questions out, and is certainly at liberty to add as many more as it may see fit. I believe that is the intent of this resolution.

Mr. Humphrey.—May I endorse what Mr. Chester has said. Mr. Chester has stated the situation exactly. Mr. Davis suggested that if this question was adopted, the Board would have no right to make any change. Dr. Humphreys inferred that there could not be any additional questions. That was not the question; these questions should be submitted to the members of the Society; this meeting having approved them, they are not to be changed.

Mr. Humphreys.—Dr. Humphreys did not infer anything of the kind; but where we have to deal with ambiguity, as we all have, it is necessary to be explicit, and I wanted to bring out that very statement, and get it on the record, and I got what I wanted.

Mr. Leighton.—Whether or not the action of this meeting binds the Board of Direction I think is relatively unimportant. The im-

portant feature of this discussion is that it will be of assistance in helping our fellow members who are not at this meeting, who are out on the plains, and in the hills and in the sage brush, to find out what we here think about it, and to give them ideas upon which they can base their opinions in returning their answers to this questionnaire.

I think, Mr. President, that it may help the members here to hear a few truths about things as they appear out there in the hills and in the sage brush. I do not know how many are here from that part of the country, but I assume the majority of the people on the floor are from District No. 1, and I assure you that that is a very small part of the country.

I would like to be merely a reporter, and that which I shall say is not necessarily a reflection of my own views. It happens that during the past year I have been in rather close touch with the engineers of the country through their various organizations. In fact, I think that few people in the engineering profession have had so fortunate an opportunity as I have to learn what the engineers of various Societies are thinking about, and how they feel.

To my amazement I find that of the many Societies in the United States with which I have come in contact and from which I have had reflections, there is no body of men so discontented with their organization, and so ready to enter upon vitriolic sage-brush talk as the members of the American Society of Civil Engineers. I do not reflect their views. I am merely telling you the fact. There is great discontent among our members. Of course, there is among others. And that discontent arises from the fact that the engineers of this country are tired of bearing the reputation of being disinterested citizens and holding aloof from their fellow citizens.

I think that reflects my views in a large degree also; but bear in mind I am merely a reporter, and in answer to Gen. Black I want to say that the thing which the engineers of the country want to accomplish and hope to accomplish is freedom from that inertia which has given them a national reputation of aloofness, and which makes everybody outside of the engineering circle believe that the engineer does not care "a hang" what becomes of the country, so long as he gets his fee.

There are a great many organizations in the United States, Engineering organizations, and some of them function well, and we all have had brought before us in the last year or more the spectacle which my friend from Washington, Mr. Ralston, gave to you this morning.

There is an association known as the American Association of Engineers. We are of many minds concerning that Association, but the one thing about it which attracts members to it is the fact that it is different from anything else. Whether or not that difference is commendable I do not care to state. You have your own ideas on the subject; but having been the titular head of an association of Engineering

Societies for a year I want to bear testimony to the fact that there is one engineering organization in the United States that can get together and pull together for the main purpose, and they do not take up valuable time quibbling about it either.

The Engineering Societies of the country want to take their proper part in the public affairs of the nation. If that means going into politics, then they want to go into politics. Perhaps they might put some sort of leaven in it that might improve politics, and I do not know of any function that would be more beneficial to the country than the leavening of the country's politics.

Now, this report of the Development Committee, the joint report, about which you have all read, has been received with open arms by the outside members of this Society all over the country; they are looking at this meeting here today, and upon the results of this meeting they are going to base their future action. Whether or not that is a wise decision I do not know, but it is nevertheless a decision; and they are not going to hold their allegiance any longer to an organization that denies them the privilege and the pride of citizenship that they want. They want to be a factor in this country's affairs. They were a factor in this country's affairs during the war, and they got used to it and they like it, and they are not going to go back to their old lair. I think we may as well make up our minds about that. And mind you, I am merely speaking as a reporter.

I believe, candidly, from all the information that I get, country-wide, that if this Society does not come out upon a broader plane, and take a stronger part in National and State and civic affairs, and encourage its members to become factors in the citizenship of this country, that we will have a sorry spectacle so far as this organization is concerned.

There are a great many of our members who would like to be loyal to this organization, but they are not going to stick by it forever. Some of them have already gone over into another organization, and have divided their allegiance. They are not boosting for this Society, but for the other one. Now, that other organization has many things to commend it. Perhaps we may not believe in its entire propaganda, but it has opened a National headquarters to reach men whom we have never tried to reach, and it has also opened up a National headquarters and a focus for those members of our own organization who are tired of our inaction.

In short, the impression which I gather from a pretty broad and intensive survey of the country is that this development programme or something very like it, should be adopted; and moreover, should be adopted very quickly, because time just now is of the essence of things; and there is another organization that is not quibbling at all.

Mr. Whinery.—Mr. President, in view of the fact which I mentioned when I was on my feet before, I move a substitute for the motion that

is now before this meeting, to this effect, that this meeting approve the recommendations of the Board of Direction, and that that course be followed. I think that that is due not only to proper parliamentary procedure, but it is due out of respect to our Board of Directors. They have, after a careful study and consideration, got all these reports. They have mapped out a programme which they think it wise for this Society to follow. The ground covers pretty nearly the same as this resolution, as I understood it. I do not object to any kind of discussion of the matter here that may be wise and proper and useful; but it seems to me, I repeat, that as a matter of parliamentary procedure and out of respect to our Board of Directors, I should make this substitute motion.

Mr. Williams.—Point of order.

The President.—I do not think——

A Member.—I would like to ask that each speaker when he gets up announce his name.

A Member.—What is yours?

C. E. Fowler, M. Am. Soc. C. E.—My name is Fowler, of New York. I wanted to say that many of these gentlemen getting up are well known in their specialties and among their special friends, but I had to ask who Mr. Leighton was. If we had known who Mr. Leighton was, we would probably have placed more——

F. C. Noble, M. Am. Soc. C. E.—Mr. President, I wish to second the motion.

Gen. Black.—Gentlemen, we have heard a very eloquent and persuasive address from Mr. Leighton. On page 15 of the advance copy of the report of the Special Committee (J. W. Alvord, Chairman), near the bottom of the page, is contained the sentiments of one of the members of the Committee as to his reasons for joining the Society. They were also my reasons for joining the Society. I believe that those reasons still stand, that this Society can make itself so strong and so necessary that no young engineer can afford not to be a member, and no older engineer can afford not to take his part.

Mr. Leighton said a very good thing about the leaven needed in American politics. There is no question about the individual duty of the members; but is that the object of the American Society of Civil Engineers? Isn't the object more clearly and truly stated on page 15 of this report, which you all have?

It is a very dangerous thing for such a body as the American Society of Civil Engineers to attempt to get into a large movement. Many of us are too busy to go in and take active part in measures which we might oppose or which we might support, if we knew about them. We have seen in our country lately a law put in the Constitution of the United States and our statute books, which was carried through by a small organization, as I believe, contrary in its present form to the will of the majority of our people.

A MEMBER.—No.

GEN. BLACK.—That is your opinion. I think time will show that my opinion is correct. I say, gentlemen, that the law in its present form is bad, because there is a majority of the members here today who themselves will violate that law whenever they get a chance. A law of that kind is a bad law. The objects are good; that is another matter.

But, gentlemen, there comes the danger of taking a body of this kind, organized for the advancement of engineering, for the advancement of engineering science, out of its proper sphere. The mere fact that as a Society we do or do not go into these public questions has nothing whatever to do with our duty as citizens.

That the engineers of our country should take a greater part in the affairs of the country is undoubted; but should it not be an individual part? Is it wise to change completely the fundamental ideas of the Society, the promotion of engineering science, simply because in this time of change and unrest the spirit of unrest passes through us all?

There are many of us today who are for reform, who are always for reform—right or wrong, for reform. I do not think that is a very good thing. We are trying all sorts of experiments, some good, many bad.

I think some of the propositions advanced by the Committee on Development are most excellent. I believe that we should affiliate more with the other societies; that we should do what we can to promote the general welfare of engineers; but how we are going to go into National questions I cannot quite see without going outside the objects for which this Society was founded.

We can increase our usefulness. I doubt not at all that the proposition of making the sections of the Society more active and permitting greater intercourse with them will inure to the benefit of the Society. The papers discussed and presented there will come to the Society, and after scrutiny by the proper Committee here add immensely to the knowledge of engineers in general. But I think before going into a generally stated proposition like this first resolution we should consider very carefully what it would lead to. It may lead to anything.

There have been certain explanations given, but they do not explain to me yet. The statement is entirely too general. That we should be a great force for engineering is undoubted. Everybody will assent to that. How is that force to be exerted? That is not explained. I am afraid of a general resolution of that kind, because it can be taken advantage of, and under the guise of authority be used for purposes that the Society would not intend at all.

Doubtless reform is needed. Doubtless we could do things, but let us be careful in making our statements in a general meeting. We

really get together once a year. Let us be careful to define clearly the proposition and see what we want to do, and what we do not want to do; and I think whatever we do we must not get away from the aim of the Society as stated here by a member on page 15, already referred to.

Mr. Humphrey.—May I just inform the members that Gen. Black, when he refers to page 15, is referring to the report of the Special Committee of the Board of Direction and not to the report of the Development Committee; and I would like to call attention to the fact that the Development Committee says on page 9 of its report that the American Society of Civil Engineers should continue to pursue the objects for which it was formed as expressed in the Constitution. (Quotes.) Then it goes on and recommends that the Society become a national force in economic, industrial and civic affairs. How? In co-operation with the other engineering organizations, which is now being done by the machine set up by the Board of Direction through the four Founder Societies and Engineering Council.

It simply allows the members to say whether that method of pursuing welfare work, interest in civic affairs, shall be carried on and shall be approved by the membership. That work was carried on without a referendum vote. We are asking for a referendum vote to see whether the members of the Society feel that the societies should co-operate along that line in these matters.

It does not mean that the Society should participate as a whole in that work, but it means that it lend its support to it through its properly accredited representatives.

A. S. Baldwin, M. Am. Soc. C. E.—I would like to ask, what is the status before this meeting of this advance copy of the report of the Special Committee. It is a report to the Board of Direction, has just been passed upon by the Board of Direction, and is now submitted to this meeting with authority from the Board of Direction, or if not, what influence has this had in the resolutions that have been prepared and are now before the house?

A Member.—None.

Mr. Hazen.—Could not this question be replaced by a statement that the Society will give a more cordial support to Engineering Council in carrying out its efforts.

It seems to me that that is what it means, and a straight statement to that effect would be better and would have the support of the members.

Mr. Humphreys.—I would like to reply to Gen. Black particularly. First, though, I will agree with him. I do think in a matter of this kind we must recognize that at present in the United States there is a passion for reform, reform of most anything, and without due consideration. That is what I have been pointing out, that whatever we do, we should do it carefully, though not slowly.

I agree with this first resolution, or question, offered by Mr. Humphrey, though he may not have thought so. I absolutely disagree, as I understand Gen. Black, that we should confine ourselves as engineers, and as organized engineers, simply to technical matters, though it is pretty hard to draw the line. For instance; if you stop to consider, gentlemen, where is the line to be drawn between engineering and many other of the activities of the United States? There are many public questions which come up, in which it is eminently the duty of the organized engineers in this country to have their say, to guide the country aright; and I do not propose to be misunderstood, or as standing in the way of proper reform—what little standing in the way I could do.

Mr. Hazen has pointed out one activity that is now in existence. I take this occasion to say a word in regard to the Engineering Council, as I am one of this Society's representatives thereon. I understood last night, at the dinner of the Officers, that the Council did not make the progress that I had hoped it would make. Was rapid progress to be expected when we had to bring in four Societies, the Founder Societies, having radically different ideas on some subjects? Yet we did thresh out some subjects and bring ourselves into line.

We found in one Society that the representatives were not in accord with their own Board, but came into accord with us and the other three. Now, great progress had been made in the last year or so in the Council; and I believe that the best way to bring about the results, as far as I am now talking with regard to public affairs connected with engineering topics, is through Engineering Council.

In other words, we have got the agency, and let us develop it. Now, you cannot develop it unless you give it more support, and you have got to give it more money. As I said last night, one member of this Board put up $25 000 to enable us to go ahead with the work—paid it out of his own pocket. We do not want to be dependent upon any one man; and if I have my way all that money will be returned to him, and then we will get the money from the organization. To that end we are to have a meeting on January 23rd, the Boards of the four Societies will meet with Engineering Council, to see what can be done.

One word more that is practically repetition. I am, and have been for many years—probably long before many of the men who are now talking in favor of it—in favor of bringing the Engineering Societies, and engineers generally, into the public affairs of the United States, so that the country should be prevented from making the asinine moves that it has made, because it did not understand Engineering.

William H. Bixby, M. Am. Soc. C. E.—I wish to ask a question for information. In the Special Committee's report, on page 2, it says that the report of the Committee on Development contains four issues, which are believed to be most vital. The second of these refers to the

formation of a new National organization, while the third raises the point whether it is well to develop the Engineering Council. On page 3 of the report it says that it recommends full discussion and the submission of four questions to the membership.

The point in my mind is whether the questionnaire that has been referred to in the resolution now before the meeting contains those four issues recommended to be submitted to the membership of the Society, or whether they substitute something else for it. I would like to know. I think that is quite important.

THE PRESIDENT.—I cannot answer that, but I think the only question that is really before us now is not the question of anything else except this one questionnaire. It seems to me that anything that is pertinent to that we can discuss here now. The other matter can be taken up later so far as the report of this Special Committee or any other matters pertaining to development is concerned; but I think really the question before us now is the first question.

MR. WHINERY.—May I not ask for consideration of the motion offered by me?

THE PRESIDENT.—I am going to go to the limit so as to give everybody an opportunity. I think before I could consider the motion that you made we must do away with this first question; and if a point of order is not raised and carried, I will give you an opportunity after that is considered to introduce it, if I am allowed to do it, but I cannot do it until this question is disposed of.

MR. WHINERY.—Without undertaking to differ with the presiding officer, for whose judgment I have the greatest respect, it seems to me that the motion that I have made is not only in order but takes precedence of the motion that you speak of. This is the first article in this resolution. It is a motion to substitute which takes precedence of the motion preceding it.

THE PRESIDENT.—Then your motion is to substitute that for this. Is that a substitution of the motion that was made to take this up?

MR. WHINERY.—Precisely.

MR. HUMPHREY.—I would like to raise a point of order on that. It seems to me that the offer of a substitute motion would have been in order when the original resolutions were offered, but the proposal was made that we should take this up item by item. Therefore, the motion is not in order. Does the gentleman want to substitute for the resolution the Board Committee's Question No. 1, or what does he want to do? Now, when we come to go through this resolution if he wants to offer a motion of substitution, I think he would be in order.

THE PRESIDENT.—I think, Mr. Humphrey, that we agreed, and it was so voted, that we should take up this first question. Now, if there is anything that pertains to this same subject after that question is disposed of, I think it can be introduced before we take up the second.

If I am overruled that is all right. As I say, I am going to give all the liberty I can.

MR. WHINERY.—After we passed the resolution that the consideration of this whole question be taken up at 2.30 o'clock, which we are proceeding to do, and argue it, it is perfectly practicable, not only from the standpoint of reason, but parliamentary law, to amend even that motion within the action taken then. I am not opposed to this discussion; I am anxious to hear it; but it seems to me that having a Board of Direction in whom the American Society of Civil Engineers has confidence, that Board of Direction having proposed a programme and recommended a plan to be operated by the Society in considering this question, out of respect alone, if for no other reason, we ought not to allow some other plan to be substituted here in place of it.

THE PRESIDENT.—Is that motion seconded?

A MEMBER.—Yes; I second it.

THE PRESIDENT.—I am going to leave it to the members. The question is on an amendment, as I understand, or a substitution, is it not, Mr. Whinery?

MR. WHINERY.—A substitution.

THE PRESIDENT.—A substitution of this first motion that we do what? I shall have to ask you just exactly what that motion was.

MR. WHINERY.—That this meeting approves the report of the plan for conducting this matter proposed by the Board of Direction of the Society, and read in the report this morning.

THE PRESIDENT.—You mean the questions that were presented through the Board to this meeting?

MR. WHINERY.—Precisely; the Board of Direction recommended this morning a particular course which this matter should take. They recommended that it would be desirable that a set of questionnaires be sent out very similar to these before us; and I have no objection to these whatever. All that I ask is that we follow the suggestions of the Board of Direction rather than that of any number of members who may be present at this meeting.

MR. HANSEL.—Mr. President, I do not understand that we have adopted the report of the Board of Direction.

THE PRESIDENT.—It was presented this morning.

MR. HANSEL.—I do not understand that it stands before this Society in any other shape than that of any other Committee of this Board, namely, the Committee on Development. If I am in error I hope you will advise me.

THE PRESIDENT.—I think the report was presented this morning. The question is on the amendment.

MR. DAVIS.—In order to clear up what the gentleman is talking about, I would like to read the resolution as it was read this morning. I shall not read the preamble.

"Be it Resolved: That the Board of Direction recommends to the incoming Board of Direction that a Committee of seven be appointed to prepare and submit to the membership forthwith necessary questionnaire or questionnaires. . . ."

(Reads remainder of resolution read at the morning session.)

The Board of Direction is expected to have a meeting today, and the Committee of three appointed by the old Board to make nominations to the Committee of seven, makes those nominations as follows:

A. N. Talbot, Chairman; Leonard Metcalf; M. S. Ketchum; Harry Hawgood; J. C. Hoyt; H. S. Crocker; C. E. Elwell.

(Later the name of R. A. Cummings was substituted for that of H. S. Crocker, at the request of the latter that his name be not considered.)

You see that is a Committee ideally representative of the country and contains the names of gentlemen residing as far east as Boston, and as far west as the city of Denver. It is as representative a Committee as it was practicable to obtain. The three members nominating this Committee were all members of the incoming as well as the outgoing Board of Direction, and the whole object of this is to expedite action.

This was done also upon the theory that a questionnaire in detail could not be as wisely worded by a meeting that has as much business before it as this meeting has, with only a few moments of general discussion without even a printed copy of the question before it, as well as it could be by a thoroughly representative Committee like this.

As one gentleman has said, the wording of that questionnaire is extremely important; and to the most of the questions formulated in the resolution that is before you, I have no objection, but to two of them I have objection because I think they will be differently interpreted, and if the matter goes on to debate on these individual questions, I will point them out. But the theory was that this action is not a recommendation to this meeting, because this meeting is expected to make such recommendation as it chooses to the Board of Direction.

Now, if you debate that questionnaire without any authority to modify it, that, of course, will go out, if this Committee sends it out; and probably this Committee will function in that way. Somebody has to do it, and as I understand the resolution, it would not prevent the Committee from still functioning; but you would have to debate the question, and give out other questions, which would not have the authority of the Annual Meeting back of them. I have no objection to this except in one respect: There might be ambiguities. I do not believe there are a dozen people that have read these questions; probably not 1% of this meeting will have an opportunity to read these questions. They hear them read from the stage. They misunderstand or mis-

interpret something, and there is danger that there will be ambiguity getting in, as I know there would be under some circumstances.

We may be able to remedy that; but I think it is unwise for this meeting to fix the form of these questions—recognizing the fact, as Mr. Leighton has stated, that this meeting is more representative of District No. 1 than of all of the rest of the country. If these seven gentlemen, who have not yet been appointed on this proposed Committee, be appointed, I know of no body that is more representative of the engineers of this Society than this, because they are men who have been elected for that purpose.

The next question is: Do you want to tie the hands of the new Board of Direction, who have not yet been tried, and to whom it is, to say the very least, discouraging if not discourteous to pass a resolution of want of confidence before it is even organized? Do you want to do that?

I said from the platform today that I am a progressive, and I am just as progressive as anybody who is here, I believe, according to my own definition. I want to point out the fact that the Chairman of this proposed Committee is, in my belief, just as progressive as anybody, and that he has the confidence of this Society and of the country at large, just as widely as any man in this Society has that confidence, and that you cannot railroad anything over.

I want to point out the other fact that Mr. John C. Hoyt, of Washington, is to be a member of the proposed Committee, and is just as radical as Mr. Humphrey, and carries on his shoulder a chip not quite so large.

Mr. Humphreys.—Mr. President, may I ask for information if Mr. Whinery's substitute motion should pass, Where are we at? What will then be before the House?

The President.—Well, that is what I have been trying to learn myself.

Mr. Humphreys.—I think it is vitally necessary that we should know—particularly in view of the purport of the remarks made by the incoming President, which I think should be given the most careful consideration.

The President.—It was rather indefinite. I was trying to find out, and to see if I could verify in my own mind what he was getting at. We have presented here today, of course, the action of the Board of Direction, and I think Mr. Davis has well explained what the Board has proposed to do. But the Board also approved of certain questionnaires to be sent out and authorized them to be presented at this meeting to get its consent.

Mr. Humphreys.—I suggest, Mr. President, that Mr. Whinery be asked to tell us what he thinks would be the order of business if his motion passed.

MR. WHINERY.—As I have said, I think there is no objection to the fullest discussion of this whole matter here, including this very set of resolutions that have been offered. I want to hear what others have to say. My point is that a plan has been outlined and prepared by our Board of Direction for dealing with this question and it would be disrespectful and unparliamentary to adopt something different from that. I have no objection to discussion. I am not trying to cut off discussion of this matter here or the expression of opinion of this body as to any of these things here; but I am simply insisting that we pay the respect to our Board of Direction that belongs to it.

THE PRESIDENT.—I think the members would like to know something definite, if you will include something definite in your motion so that we can understand just what it is. I think that is very important.

L. L. TRIBUS, M. AM. SOC. C. E.—Mr. Whinery's resolution is a very proper resolution, as a substitute, to adopt the recommendations of the Board of Direction. Among those recommendations is the request that this meeting offer suggestions to such Committee as may be appointed to formulate the questionnaire.

If we pass this resolution that Mr. Whinery offers, it simply carries out just what this meeting wants to carry out. After passing it, we are ready to take up the set of resolutions. Those resolutions would then be, if we modify the verbiage, simply suggestions to the new Committee of the Board, to be included, not exclusively, in the questionnaire—a perfectly logical thing to do, a perfectly simple thing to do.

THE SECRETARY.—May I say a word? I want to correct the impression that I derive from what the speaker said a moment ago, that the Board of Direction have recommended certain questions to be sent out. That is not true. The Board of Direction formulated certain questions, and brings them to the attention of this meeting for discussion, with the end ultimately in view that they shall be sent out according to the suggestions of this meeting. The Board has not recommended any of these.

MR. WILLIAMS.—Mr. Chairman, I do not understand the situation to be as indicated by the preceding speaker, nor exactly as indicated by the Secretary. It is possible that he is right, probable that he is; but, as I see it, the Board of Direction has passed some resolutions. It has passed them, and this meeting has nothing to do with them. It has perfect authority to pass a resolution, and it does not come here and ask us to approve it. It informed us of what it had done—appointed a Committee to see to sending out whatever this meeting proposed should be sent out—and in practical conformity a motion is made to send out certain questions, and we are trying to consider whether these are what we want sent out. The question is perfectly clear, either we do or we do not.

If we do, let us say that we do, and the Board sends them out. It is not prohibited from sending out other questions. If we do not want a certain question sent out, let us say so, and if the Board thinks it really ought to be sent out, I think it has the authority to send it out.

Something has been said here about the standing of questions which might be promulgated by the Board of Direction, as compared with questions that might be promulgated by some other people. I want to read a statement from the published report which is placed in our hands by the Special Committee of five members of the Board of Direction. It appears at the top of page 4 of that printed report.

"In general, its recommendations resolve themselves into two classes: 1st.—Fundamental changes in our Constitution to further the creation of a new organization for co-operative work with other Affiliated Societies, and for professional and public welfare."

I want to say, gentlemen, that that is absolutely false. The Board of Direction is amply qualified to enter upon the programme for co-operative work which is laid down by the Development Committee, without dotting an "i" or crossing a "t" in the Constitution; and when that Committee wrote that, they showed they had not given to the report nor to the Constitution the study which they should have given, before they ventured to advise the Society as to what the report of the Development Committee meant.

I think that those who were on that Development Committee and who labored weeks where the Board has labored hours, are better qualified to say what questions should be sent out to the membership of this Society to elicit from them an answer as to their sentiments on those questions than are the members of the Board of Direction who have just come in, and who will sit down this afternoon and prepare a questionnaire.

F. C. Shenehon, M. Am. Soc. C. E.—I have had placed in my hands the report of what is known as the "Alvord Committee", a committee of the Board of Direction. The conclusions reached by that Committee are widely different from the conclusions reached by the Development Committee. Now, I would ask a question: If the series of questions, the questionnaire presented by Mr. Humphrey, is adopted by this meeting, does the report of the Alvord Committee have any standing whatever in this meeting, or is it simply killed unheard? That is the question that is in my mind.

It appears to me, if we are going to have confidence in the incoming Board of Direction, it would be very proper to settle the question by having a little confidence in the outgoing Board of Direction, and here is the Alvord report, which appears to be sidetracked as near as I can make out, and a new set of questions prepared which absolutely ignores that report.

Mr. Chester.—I want to correct a statement by Mr. Davis which seems to reflect upon the origin of these questions. Mr. Humphrey and Mr. Hoyt have been factors in their preparation. They are the product of a joint meeting of the representatives of a large number of the Sections of this Society, duly appointed to meet for that purpose, and to coin something that should be brought before this meeting as a recommendation; and those questions, as they finally appear, were unanimously adopted. I speak for Pittsburgh where there are 192 members.

I was duly appointed as a representative, one of four representatives of that Section; and this is not the result of radical action, a radical result, as Mr. Davis has said; and it is not because of any pique or anything on that order. All Mr. Humphrey or Mr. Hoyt did was well matured, well thought out, carefully considered, and finally adopted in the way outlined.

Leonard Metcalf, M. Am. Soc. C. E.—Mr. President, is it not a fact that the motion of Mr. Whinery would accomplish this result—that it would approve the suggestion of the resolution already passed by the Board of Direction that there should be sent out to the membership of this Society not only the series of questions upon which we are now passing, prepared by the members or the various organizations in co-operation with the Development Committee, but also the questions prepared by the Special Committee, or "Alvord Committee" of the Board of Direction, and also any other questions that might appear to be necessary to make clear the purpose of the questions submitted by either of those organizations or submitted by the Development Committee?

I assume that the sentiment of this meeting and of the Society generally is in favor of progress, the progressive movement. There may be a difference of opinion as to the extent to which we should throw overboard old meetings, old organizations, and build up new ones. It seemed to the members of the Board that in so important a matter as this the questions should be put before the membership clearly in their alternate form.

Now, if I understand the questions which have been presented for discussion this afternoon, there is one among them with regard to the formation of a society for carrying on the welfare work. There are many, on the other hand, who feel that it would be desirable, as the Special Committee has pointed out as one of the alternatives, to broaden the scope of the work of Engineering Council, believing that a modified form of the Council, a broadened form, would get together more quickly, would function more effectively, than a new organization, when you consider that time is required to build up any effective organization of that sort.

It had seemed to the Board, and it seemed to me personally, desirable that questions of that sort, and I select that merely as an example, should be submitted in their alternate forms to the members for adoption.

For the rest, the resolution of the Board merely has to do with the machinery necessary to get these questions before the membership at the earliest possible moment. If you do not like the Committee, it is perfectly possible for you to say so, and suggest the appointment of another committee; but it does seem to me that in a matter which is going so vitally to affect the future of this organization that we ought to have clearly before us the alternatives which are open.

MR. HUMPHREY.—I had not expected to say anything about the "Alvord Committee" Report. I did not believe that it was before this meeting, but I must say that I have carefully read the Alvord report, and there is hardly a paragraph that does fair justice to the report of the Committee on Development.

I call attention to one thing: In commenting upon the budget of the cost of carrying out these activities, it says by inference that the Development Committee recommended the abolition of the excess dues of $10 paid by those resident in District No. 1, and there is added, therefore, $15 000 to the budget for the Development Committee, making a total of $42 580.

They recommend four questions. Three of these relate practically to the external organization; similarly to Engineering Council. The other calls for the raising of the dues by not more than $10. The inference would be that to carry out the recommendations under the budget, this plan, as recommended by the Development Committee, would involve $42 580; and to carry out their entire project would take $85 900.

As a matter of fact, if the report of the Development Committee were adopted only so far as it related to external relations, the recommendation of that Committee is that it will cost $8 500; and there is not a single line that intimates that the dues of the New York members should be reduced.

Throughout it makes statements that are not fair. The second question says, "If so, shall it assent to the formation of a new and somewhat unrestricted organization . . .?" I say that questions of that kind should not have been inserted in the report, under the circumstances.

Now, all we are asking, Mr. President, is not that the Board of Direction shall be suppressed, and shall not send out a questionnaire; but we have an idea that the Annual Meeting should be something more than a rubber stamp; we have met here, as Corporate Members, in the past, and simply approved what is being done. The members of this Society who attend the Annual Meeting are quite as competent

as the members of the Board of Direction to express an opinion and those questions that are submitted are clear-cut. If there are ambiguities in them, Mr. Davis can point them out, as they are taken up.

The local associations in this country are needed. Outside of Districts 1, 2 and 3—No. 1 has no New York section—there are sections in every district in the country. May I call your attention to the fact that it has been said that the local sections in this country only represent one-sixth of the membership. Now, as a matter of fact, if any one wants to study the real figures, taking Corporate Members of this Society who have the right to vote, you will find that there are 7 100 members—subtracting the number who live outside the United States—there are 7 100 members in the United States. There are in the local sections today nearly 2 500 members. Now, the relation of 25 to 71 is not one-sixth; it is about one-third.

I would say furthermore, Mr. President, that the men who reside in the local sections are nearly 50% of those who dwell in the greater cities, where they have local sections; and the men who are not in that group are men who are so scattered that they have not been active in the affairs of the Society.

Outside of the New England States and New York, local associations throughout the country for the past year have been debating these questions, and the questions in that resolution no more reflect new matter than anything that is stated in the annual presentation of the Board of Direction.

They are the facts, the crystallized facts; and why should not the Annual Meeting have the privilege of asking the Board of Direction to send out those questions? Why should we be suppressed? It has been that attitude that no one can put anything through, that the Board of Direction must do it, that causes dissatisfaction.

Now, for the past ten years the Society has done very little, and there are a great many loyal members of this Society who think that the time has come to do something; and I hope the Annual Meeting will pass the resolution with a word to our Board of Direction that we here at this Annual Meeting believe in these fundamentals and that these questions should go out to the membership.

S. N. Castle, M. Am. Soc. C. E.—I have listened today with a great deal of interest to the varying opinions expressed by the members here. It has seemed to me that the fundamental issues have been entirely obscured, and I am not sure that some of them have not been purposely obscured.

The fundamental question before the Society is whether the Society exists for the benefit of the members, or whether the members exist for the benefit of the Society? And in view of the statements made here today, I am rather inclined to ask, for the benefit of a few in control of the machinery? That is a bold and bald statement, but I

want to say that the members are the ones that ought to be considered in any action which concerns the interest of the Society as a whole.

Question 1 concerns the adoption of the principle of becoming an active National force in economic, industrial and civic affairs. I attended the meeting of the Society on December 3d, 1919, at which the Committee's report was presented. I was rather astonished at the statements made throughout. It seemed to me that the membership failed to perceive that our civilization today is industrial; that all the elements which go to make up the problems of production of goods, in which Civil Engineers have just as vital a part as the Mechanical or Electrical Engineers, was a point which should be considered by this Society. The human element in industry, that is to say, the questions of human engineering, are just as important a part in the production of goods as the material element of engineering.

The statement was made at that meeting that the American Society of Civil Engineers was interested only in the details of the scientific specialties which they represent, but that the human element was entirely beyond its scope. Gentlemen, I disagree. If we are to become a live, vital factor in the history of the nation, we must take into consideration the human element, the human factors; on the well-being of the workman's industry depends the value of the nation. By that I mean that only in so far as each individual worker progresses in physical well-being, in educational and moral qualifications, does he become an asset to the nation as a whole.

Mention has been made of the "Alvord Committee" report, Mr. President. If I had a hat on I would like to take my hat off to those who conceived it. It is an extremely clever document, but a careful perusal of it leads me to believe that it is an effort to negative the report of the Development Committee; and it seems to me that inasmuch as the Development Committee represents the membership, whereas this report is the report of a committee of the Board of Direction, when it comes to the discussion before the membership the report of the Development Committee as a whole should take precedence.

Emphasis is made here on the question of Engineering Council. Gentlemen, it is a very delicate subject to speak about in public, but Engineering Council represents the official organization of the Society and does not represent the rank and file of the membership. An effort is being made here in the Development Committees of the four Founder Societies, to put forward some organization whereby the rank and file of the membership of these societies can find expression. And I think, gentlemen, that considering the substitute motion that Mr. Whinery has put forward here, you want to bear in mind that what we are getting at is to express ourselves as individual members, and not merely through the organization of the Society.

W. J. BACKES, M. AM. SOC. C. E.—I would like to take exception to the statement of Mr. Humphrey that New England had not given this matter consideration. I would like to say that we have discussed this matter and have given it very thorough consideration, and that we had endorsed, in general, the conclusions of the Committee on Development.

We all feel that it is absolutely necessary that this Society recognize that this crisis is the turning point in its career, because if we cannot recruit into our organization the younger men, we are going to be lost in ten years. It may not show now, but it is going to show later; and we are making no appeal to the young men unless we can get them together.

The young man has neither the time nor the money to come here, but through the local sections it will be possible to get these young men together and make our appeal to them direct. And furthermore, I believe that an appeal should be made to those young men who are in our colleges, and a place should be made for them so that they will feel that they are a part of the National organizations; because if we do not get these men they are bound to be led off into some other organization, particularly this association that was mentioned here to-day.

They are making heavy drafts among the younger men, and with proper leadership they are going to supplant, they are trying to supplant, the Founder Society.

MR. HUMPHREYS.—Might I relieve Mr. Backes' mind by saying, as President of Stevens Institute, that he need not worry about the boys over there. They do not show any such tendency.

THE PRESIDENT.—He comes from Connecticut—New Haven—perhaps they are not the same.

MR. HUMPHREYS.—We have lots of Connecticut boys with us.

I would like to say one word with respect to the remarks of the gentleman next preceding. I would like to ask how any organized body like the Engineering Council or the Board of this Society can represent the members, if they do not now. For instance, there are three new men, if I recollect, who go in this year. Those men were endorsed as representative men by their several Sections. According to this gentleman, I suppose, the instant they get inside of the Board of Direction they become organization men, and do not represent the membership. How, then, are you going to get representatives? The only suggestion I can make, to help the gentleman out, is to have a Soviet Government.

MR. WHINERY.—I think the great sentiment in the Society is that we should make progress, and progress along the best lines. The point is that we ought to consider in the most careful and deliberate manner what is progress and what is not progress. To me it seems, in addition

to the reasons I have already given, that that is best secured by following the method outlined in the report from the Board of Direction.

There is no objection, as I said before, to discussing the questions here and to expressing opinions; but let the matter take the course outlined by the Board of Direction. That is the simple question on which we are called to vote now, not on any of this extraneous matter that has been brought out.

THE PRESIDENT.—I want to say that we have discussed this matter one hour and three-quarters, and do not seem to be getting anywhere. If there is anybody else that wants to discuss it, all right, but if there is not——

MR. RIGHTS.—I want to say something in defence of the Board. The statement has been made here to the effect that some of the statements in this "Alvord Committee" report are absolutely false; and the resolutions offered by Mr. Humphrey, I understand, are to the effect that the questions must be submitted without the change of letter or word. Evidently you do not trust your Board of Direction. If you are going to put your resolutions through that way, you do not trust them.

These men on the "Alvord Committee" are all hold-over men, and are on the new Board. I do know that they have devoted a great deal of attention to this matter. They did as much work as would comprehend an elaborate engineering investigation. They did the best they knew how, and they submitted their report. The Board of Direction in turn has submitted to you for your consideration a series of questions; and in addition to that, the Board has asked you to express yourselves as to any other questions which you would like to have submitted.

Now, then, if you have no confidence in them, you probably have no confidence in the new Committee that Mr. Davis has mentioned. Why, you had better take the whole thing out of the hands of the Board of Direction and run it yourselves. I am going off the Board, but I just want to speak in defence of it.

The Board of Direction, as near as I can see from three years' experience in it, is representative. It has its ear to the ground all the time trying to find out, not what New York wants, but what the members outside want; and one of the troubles is that we cannot hear anything as to what they do want.

You probably know, although you do not think of it, that a change in the Constitution can be brought about, or action on the Constitution can be brought about, by five members? You can pick up five members on the street, submit a proposed change in the Constitution; and it is mandatory upon the Secretary to submit that to the next semi-annual meeting. The Board has nothing to say about it.

I want to know if this Board of Direction has been misrepresentative for the past ten years, where are all these gentlemen? Have they not been able to find five men who agreed with them? There must be something the matter.

Now, I ask you to support Mr. Whinery's resolution, and give this Board a fair show. They have heard the discussion. They know what it is. Give them a fair show to do what you would like them to do.

Mr. Humphrey.—I think, as the mover of the original resolutions, I made it clear that it was not the intent of the resolutions to suppress any questions that the Board of Direction may send out; that the purpose of the resolutions was not in any way to reflect upon the Board, or the splendid work that the Board was doing, but it was simply that those who had given attention to this question should express what they wanted to submit to the members.

The "Alvord Committee" did not have very much time in which to pass upon this matter. If I am correctly informed they had no meeting on the subject. The Development Committee's report represents the work of 40 men, 28 of our own Society; and they put in thirty days of solid work on this report.

I believe these men are just as competent to express the wisdom outside of District No. 1 in the east as any other body of men. Mr. Rights says they try to hear what the outside men want. They have it in the report of the Development Committee, in which the twenty-two Local Sections are represented.

What is the objection of this Annual Meeting to adopting the resolutions? The Meeting has a right to send them out; and the Board, in its resolution, has intimated that such instructions and questions as are wanted should be included. The "Alvord Committee" Report referred only to the question of external relations; and while we want to see that go on, there are those on the Development Committee who feel that the question of our technical activities and the broadening of this work is just as vital, and who think it would be a mistake to submit only questions on external relations and not on internal relations; and the purpose of these resolutions was to extend the "Alvord Committee" report by including internal relations as well.

I hope that we will adopt this resolution and that the Board will send out questionnaires with whatever questions they see fit. I know the Board of Direction has authority to send out a questionnaire whether this meeting says so or not at any time.

(Cries of "Question".)

O. H. Dickerson.—Mr. President, the gentleman here wondered if we had confidence in the Board. There are a great many members of the American Society of Civil Engineers who are wondering if you are showing proper confidence in its Development Committee. We are in touch with them, and they ask that these questions be submitted. That is the question that seems to me to be before this meeting. Is the questionnaire that they have proposed, and which they, with all their study, have considered is the essential, fundamental feature of this report, to go to the membership of this Society, or is some other person's interpretation to go?

Mr. Humphreys.—Here is the first intimation I have had that the report of Mr. Humphrey comes officially from the Development Committee.

Mr. Humphrey.—May I say to you, Mr. President, that this Development Committee in transmitting to the Board of Direction of this Society, transmitted the Development Committee report with a letter in which it set out nine questions, which it said would simplify, establish and show the fundamentals that were in that report, and asked the Board of Direction of the Society to canvass the opinion of the members on or before January 1st on those fundamentals, and report them to this Annual Meeting. That part of the report has never come to the membership of this Society. For some reason it has been suppressed.

(Cries of "Question.")

The President.—The question before the house is the motion made by Mr. Whinery that the action of the Board of Direction be approved. All in favor of that, please say "aye"; contrary, "no".

The chair is in doubt, and I am going to put that question again, and ask the members to vote by raising the right hand. All those in favor of Mr. Whinery's motion, please raise the right hand; all opposed, the same sign.

I shall have to declare the motion lost.

Mr. Humphrey.—I want to say that we have been all this time considering only one question—I do not see how we are going to go through the nine, and I am going to call for the previous question now.

The President.—The question before the house was that we vote upon this first question of the questionnaire.

Mr. Humphrey.—I withdraw that motion.

The President.—All who are in favor of this first question, "Shall the American Society of Civil Engineers adopt the principle of becoming a National force in economic, industrial and civic affairs?" signify by saying "aye"; contrary, "no." Carried.

Mr. Parker.—It has been moved twice that we refer to the original resolution, the adoption of the original resolution offered by Mr. Humphrey. That has been seconded, but I will second it also.

The President.—I do not understand that there was any original motion. I understand that Mr. Humphrey proposed to take these questions up singly.

Mr. Talbot.—As one very much interested in this subject, I trust that this call for the previous motion will not be carried. I know it is not debatable; but it seems to me that before this Annual Meeting passes upon it we should have this read again and passed upon. If there is no time between now and dinner time, let us adjourn until to-night or to-morrow. It is not necessary to go to the excursion. I should like to have some of those questions and have a chance to see what they are. It is not well for us to put it in such shape that after-

ward we will find that there have been some mistakes made; that there are difficulties or dangers in some proposed policies, that we should not take up.

We have not, so far as I know to-day, discussed in any way the merits of some of these questions. I have not seen these questionnaires. If this was submitted to the Board of Direction, I, for one, never saw the list and did not know that the Committee had presented such a list to the Board.

Mr. Davis.—Nor I.

The President.—I do not think that Mr. Humphrey or anybody else, wants to make any such motion as that, for the very reason that all of these questions ought really to be discussed as we go along. Let us take our time. It is very unfortunate, I think, that any one should make a motion of that kind.

Mr. Williams.—I move that we proceed to a consideration of the second question.

(Motion seconded.)

The President.—If that is agreeable, we will proceed to the consideration of the second question. All in favor of taking up the second question, please say "aye"; contrary, "no." We will proceed to the consideration of the second question.

S. M. Swaab, M. Am. Soc. C. E.—I move its adoption.

(The President reads the second question to the meeting.)

Mr. Swaab.—I move the adoption of the second question.

(Motion seconded.)

Mr. Davis.—May I ask a question?

(Cries of "Question.")

The President.—You have to allow questions. I am not going to put the question right off. You have the floor, Mr. Davis.

Mr. Davis.—I have risen several times to ask this question of Mr. Humphrey. He has made a very serious charge. I never knew of the suppression of that letter and questionnaire accompanying the report of the Development Committee until he told me, and I would like to know about it. This is the question I tried to ask: Is the questionnaire now before the house the same as that presented by the Development Committee?

Mr. Humphrey.—I have here a copy of a letter signed by Onward Bates, Chairman, and by E. T. Howson, Secretary, to the effect that every member of the Committee on Development has been advised that this report was submitted to the Board of Direction. It says: "The Committee on Development in submitting the attached report, recommends that a vote of the members of the Society be taken and canvassed on or before January 1st, 1920, and that the result thereof be reported at the next Annual Meeting upon the following essential

features contained in that report, together with such features as the Board of Direction may deem desirable.

"1. Shall the recommendations of the Committee on Development as to technical activities be adopted? (A, 1-5)

"2. Shall local sections be created to embrace the entire membership of the Society? (B, 1, a, b, c, d, h)

"3. Shall the Directors in each geographical district be nominated and elected by vote of Corporate Members resident therein? (B, 1, e, f, g, l)

"4. Shall a portion of the Society dues be allotted to local sections? (B, 2, i)

"5. Shall the present Nominating Committee be abolished and the officers at large be nominated by representatives of local sections in annual conference? (B, 2, j, k)

"6. Shall the present grades and requirements for membership be revised? (B, 2)

"7. Shall the code of ethics recommended be adopted? (D, 2)

"8. Shall the American Society of Civil Engineers join in the formation of the proposed National Council of Engineering and Allied Technical Associations? (C, D)

"9. Shall the other recommendations in the report of the Committee on Development be adopted?"

Those who have discussed these questions felt that matters like that of membership grades were not so germane at the present time; that if the Society voted on these fundamentals in the affirmative, it would mean, in some respects, especially in the matter of dues and the creation of local sections, an amendment of the Constitution. We are due to have an amendment of the Constitution, a revision of it, at some time, and when that revision of the Constitution comes, the grades of membership will of necessity have to come under consideration and come up at that time.

The President.—I understand that these questions accompanied the report from the Development Committee, the report to the Board of Direction by the Development Committee.

Mr. Humphrey.—It was a letter transmitting the report of the Development Committee, and I see no reason why that questionnaire should not have gone to the membership.

A Member.—Are these the same questions?

Mr. Humphrey.—Substantially,—three questions have been put in instead of two, and some other small changes made.

Mr. Hansel.—During the discussion of the report at the December meeting in New York, those attending wondered why the Committee on Development had not offered a set of questionnaires. They had

received the voluminous report and felt that if the Committee on Development had taken the trouble to desire questionnaires, it would have been stated.

I stated at that time that the Committee on Development had prepared these questions, had handed them to the Board of Direction, but I could not answer nor explain why the letter had not gone out with that report. I feel that had it gone out, there would have been a great saving of time and a greater understanding of the Development Committee's report.

The Secretary.—Mr. President, there seems to have been a suggestion, by intimation or otherwise, that something has been suppressed. The list of questions which Mr. Humphrey has just read came with the report of the Development Committee, with the recommendation that it be sent out to the membership, and a vote received and canvassed by January 1st.

If I remember correctly, that set of questions was presented to the Board of Direction at the time that the report of the Development Committee was presented. As I understand the matter of the attitude of the Board of Direction, the Development Committee was created by the Board of Direction of its own volition. It was a Committee to report to the Board.

This report was received only a day or two—I don't remember the exact date, before the meeting of the Board which was held on October 14th—you perhaps have the date there.

Mr. Humphrey.—Oct. 9th, five days before.

The Secretary.—The meeting of the Board was on the 14th. There was no time, of course, to send the report to the members of the Board in time for them to study it before they got to the meeting. The report was read to the Board in full. All these questions were read in full to the Board. If I remember correctly, in another letter of transmittal, or perhaps in the real letter of transmittal, this being another one on the side, the Committee on Development stated that its report was not finished, that it had appointed a Committee on Budget and recommended to the Board that when the report of the Committee on Development was sent out, it should be sent out when completed, on receipt of the report of the Committee on Budget.

Meanwhile the Board, at its meeting of October 14th, realizing that it could not go into this matter, could not send out these questions until the report was complete, could not send out the report itself to the membership until it was complete, with the report of the Committee on Budget, appointed a sub-committee to consider and report to it at its next meeting. The report of the Committee on Budget was received on November 11th.

That is the history of the case. I do not wish to comment upon it at all, but there was no suppression of anything. The Board of Direc-

tion did consider the whole question and thought it wiser to refer the matter to the Committee appointed by itself to report back to the Board, so that it could act intelligently, and report the whole matter to this Annual Meeting of the Society. There would hardly have been time after November 11th, which was the earliest date at which the report was complete, to have sent out these questions and got an answer in time.

Mr. Williams.—The question has been asked here, or statement made, that the "Alvord Committee" never held a meeting. Can the Secretary throw any light upon it?

The Secretary.—I know nothing about it.

Mr. Alvord.—The committee did hold a meeting.

Mr. Williams.—How many?

A Member.—How long?

Mr. Hansel.—Question on No. 2.

Mr. Humphreys.—Will somebody read the question? Let us understand it.

The President.—I will read it to you: "Shall the Society actively co-operate with other engineering and allied technical associations in promoting the welfare of the Engineering Profession?" That is Question No. 2, a harmless one.

Mr. Humphreys.—I would like a definition of "welfare", from the man who offers this.

(Cries of "Question".)

The President.—I think the gentleman is entitled to an explanation.

(Cries of "Question".)

The President.—Dr. Humphreys has asked for an explanation of a word in this Question No. 2, and I think Mr. Humphrey ought to give him an answer.

Mr. Humphrey.—Generally the word "welfare", as used in debate at the meetings of the four Founder Societies, is to cover those matters relating to the Profession and Engineering other than technical matters.

The President.—I do not need to read this question again. All in favor will please say "aye"; all against, "no". Carried.

Mr. Castle.—I move the adoption of Question No. 3.

(Motion seconded.)

The President.—It is moved and seconded that we take up Question No. 3. I am going to read it: "Shall the Society for the purposes set forth in Questions 1 and 2"—which you have already acted upon—"actively co-operate in the creation of the comprehensive organization as outlined in the Joint Conference Committee report?" Just what that means I will leave to you. Whether that means another organization, I do not know.

Mr. Humphrey.—The reference is in the resolution. Look up the Development Committee's report, pages 10 to 19.

The President.—I know that there are some members of that Committee who are opposed to that.

(Cries of "Question".)

The President.—You cannot hurry this. In my judgment it is too important a matter to hurry.

Mr. Metcalf.—There has been some division of opinion, as I have heard it expressed, as to the significance of the words as outlined in the Joint Conference Committee's report. Does that mean that this resolution intends the formation of a new independent organization, or may it, as was suggested to be possible in the report, mean the modification of Engineering Council as a possible substitute for a new organization? I would be very glad to hear from Mr. Humphrey.

Mr. Humphrey.—Mr. President, that raises the question involved in the report. The Joint Conference Committee of the four Societies—I would like to say that its report was unanimous—set up an organization to create a democratic National Council for welfare work. The purpose of that council is similar to a Chamber of Commerce. There would be no individual memberships in it, but the National Council is to be made up of delegates from local bodies, which correspond to local Chambers of Commerce.

There would be individual membership in local associations of engineers, but the National Council would be made up of representatives of organizations—a building up of the Engineering Profession from the bottom upward, for this particular phase of the engineer's work.

It was expected that if Engineering Council—I think we are all of the opinion that Engineering Council has done splendid work, but unfortunately it has got a lot of strings to it; it is not self-determining; it is not sufficiently democratic—if the Engineering Council can be made democratic and to fit into the new organization, this new organization would be the reconstructed Engineering Council, to make it more democratic.

I want to call attention to the fact that in the "Alvord Committee" report it has been stated that plumbers masquerading under the title of Sanitary Engineers could be made members of this Council. The Committee evidently did not read the Joint Conference report, which requires that applications would have to be submitted to the National Council for approval; and I am quite sure such applications would not pass the Council—if plumbers masquerading as engineers should apply for membership in that Council.

I do not need to carry coals to Newcastle. Engineering Council has passed a resolution to approve the Joint Conference report. Let us carry out the plan as organized. If Engineering Council will fit

into this—fine. If it is found that there are legal obstacles, that is another matter, but we want this single, comprehensive organization for welfare work.

THE PRESIDENT.—If this goes through, I understand it cannot be changed in any way whatever. The question is whether you would agree, or the Committee would agree, that if it was found proper to make some little change, on account of the reorganization or for the better working of the National Council, it could be done. I do not know how we could make any change.

MR. HUMPHREY.—I think if the Board of Direction and the Committee is going to consider that field, the question is not adequate. They can put another question to cover it in a complete form; but I want to warn the Board if they put out a question as to whether the present Engineering Council should be made a member of this organization, they will get an overwhelming vote against it. I do not believe in destroying. I believe in utilizing.

THE PRESIDENT.—You would like to build up what we have got; you would like to enlarge the present Engineering Council?

MR. HUMPHREY.—And make it democratic.

MR. WILLIAMS.—Mr. Humphrey, through an inadvertence, forgot to say that the National organizations were to be represented. The scheme contemplates a comprehensive National organization or Council of engineers to be composed of representatives of the National Engineering Societies in the proportion of one representative for each society for the first 200 to 2 000 members, and one additional member for each additional 2 000 members or major fraction thereof; and a representative of local, State and regional societies in the proportion of one representative for each society for the first 100 to 1 000 members, and one additional representative for each additional 1 000 or major fraction thereof. That was the fundamental organization proposal.

MR. DAVIS.—I would like to ask whether, if this question was answered in the negative by letter ballot, that would be the organization that would be adopted?

MR. HUMPHREY.—In the negative?

MR. DAVIS.—No; I mean the affirmative.

MR. HUMPHREY.—No; I do not think that would be the case at all. But again I would like to read from the report of the Development Committee. You will find in the report of the Development Committee on page 11, first paragraph, the following language: "If desired, Engineering Council can be moulded into this organization by making it more democratic and founding it on direct representation of all engineers, rather than appointment as at present."

(Cries of "Question.")

THE PRESIDENT.—Does anybody care to say anything?

A MEMBER.—I would like to have that question read over again.

THE PRESIDENT.—These are very important, and I ought to express my own opinion. There might be a different interpretation or more than one interpretation; but the question is this: "Shall the Society for the purpose set forth in Questions 1 and 2 actively co-operate in the creation of a comprehensive organization as outlined in the Joint Conference Committee report?"

You all have to understand what they outline in that report if you are to vote intelligently on this question, I suppose. Are you ready for the question? All in favor say "aye"; contrary, "no." Carried.

We come now to the "infernal" relations.

A MEMBER.—"Infernal", did you say?

THE PRESIDENT.—I don't know what you call them, I call them infernal.

MR. HANSEL.—I move the adoption of Question No. 1, Section B.

(Motion seconded.)

THE PRESIDENT.—It is moved and seconded that we take up Question No. 1, Section B: "Shall the recommendations of the Committee on Development as to technical activities be adopted?"

MR. SWAIN.—I do not happen to know just what those recommendations are that we are voting on.

A MEMBER.—Pages 4 to 6 of the Development Committee's report.

MR. HUMPHREY.—I will enlighten the gentleman. On page 4 of the report of the Committee on Development appears Section A, "Technical Activities." It provides for meetings. It recommends that the fortnightly meetings of the Parent Society be discontinued; it is expected that the New York section will take care of those meetings. And it is recommended "That the semi-annual meetings of the Parent Society be supplemented by the addition of a spring and fall meeting held successively in different sections of the country in co-operation with local sections." The system of securing papers is discussed. It calls for some study with the idea of selecting a programme of papers. The monthly *Proceedings* should be extended to include editorial work, abstracts and reviews of important engineering articles and subjects of popular interest to the great majority of engineers.

The section on Committees calls for the creation of an Advisory Committee to co-operate on questions before the Society so that the Local Sections may have an opportunity to participate in this work. Under "Standards in Engineering Practice" it states "that co-operation with the American Engineering Standards Committee" should be fostered. That is what the recommendations are.

(Cries of "Question".)

A. GIDEON, M. AM. SOC. C. E.—Mr. Chairman, I am from Manila. I have been a member of this Society for some twenty years. I have been away most of that time, so I have never had a chance to say

anything, and I believe I had better take my chance now because I may not soon have another one.

It seems to me that we are going a little bit too far. To prove to you that I am not an ultra-conservative, let me say that I have been called ever since childhood, all the radical names, as soon as they have appeared on the horizon. I have been known as a socialist, an anarchist, a Bolshevist, and everything else, although I am not any of them. I have tried all my life to be as progressive as I knew how, and that I was successful is evidenced by the fact that I served the United States on its outskirts, in Havana, and now in the Philippine Islands.

Now, it seems to me that we are taking a very dangerous course. A man who prepares a paper for the whole of the American Society of Civil Engineers will take a great deal more trouble in preparing it, will study it more, than he would for a local society, even if the local society was the New York Section.

I have read a great many papers and publications of various societies, including the English societies of engineers, and a great many others, and, as a rule, the best papers appear in the societies which have the greatest circulations, that is, the ones that are published for the benefit of the whole society. It is true, you will say that these papers will have wide circulation. However, there is a great deal of difference when one knows that he speaks to the whole Profession, rather than to only a few people, whether it be New York, Providence, Manila, or anywhere else. I have sat here listening quietly to some of the various expressions about the Society deteriorating, and if not now ten years from now. I joined the Society in 1900. I heard the first year that the Society would go to the dogs; that it was run by a clique of Directors.

I remember what Governor Flower told me once. He said, "If you want to fight the trusts, get inside and fight from there. Don't fight them from the outside; you will not succeed. Get on the inside, and fight from there". And that is what he did, I believe.

This Society does not need any catch words to depend upon for its longevity or its welfare. It is one of the leading societies of the United States; it is the leading society in the United States, and probably the leading society in the world. I am familiar with a great many of the societies all over, and even in the Philippines, we have the Philippines Society, which dies an untimely death, due to the departure of engineers back to the United States.

We need not fear for the future of this Society. This Society will keep on increasing, and keep on increasing just as fast as it needs to increase. We do not want a great many of these members who would join other societies for other purposes. The ones that join the American Society of Civil Engineers join it for the reason that it is the leading Engineering Society in the world, and they want to belong to

it. They want to give benefit to the other members and they want to benefit somewhat themselves.

I admit that some reforms will have to be made from time to time, but if you want to take the advice of a semi-stranger, do not reach out too fast. Go slowly.

THE PRESIDENT.—The question is: "Shall the recommendations of the Committee on Development as to technical activities be adopted?" All in favor of that please say "aye". Contrary, "no". Motion carried.

MR. CASTLE.—I move the adoption of Question No. 2.

(Motion seconded.)

THE PRESIDENT.—It is moved and seconded that we take up the second question under Section B: "Shall local sections be created to embrace the entire membership of the Society?"

MR. DAVIS.—I am afraid there is a misconception. The adoption of one of these questions to go into the questionnaire does not mean that we answer it "yes" or "no". The answer to that last question does not abolish the local meetings but simply asks the question from our membership whether or not they shall be abolished; and that is the case with all of these questions.

THE PRESIDENT.—The whole action of this meeting is in directing the Board to send these questions out. That is all the authority that this meeting gives.

(Cries of "Question".)

The question is: "Shall local sections be created to embrace the entire membership of the Society?" All in favor please say "aye". Contrary, "no". Carried.

V. H. HEWES, M. AM. SOC. C. E.—In calling off the different questions, I would suggest that the various sections that are referred to in the Committee's report be read at the same time so that those members who are not thoroughly familiar with it may know what they are voting on.

THE PRESIDENT.—I have read each one, and if the members do not know what they are voting on I cannot help it.

THE SECRETARY.—In order that there may be no mistake, I would like to say that these questions by themselves read without reference to this report—without reference to any report.

MR. HUMPHREY.—The Secretary will find after each question a reference to the report of the Committee on Development to the Board of Direction of the Society.

THE SECRETARY.—The point I make is this—when these questions are put that part is not read, and I want to know whether it is to go in.

MR. HUMPHREY.—It surely is.

THE PRESIDENT.—The question now before the meeting is No. 3: "Shall the Directors in each geographical district be nominated by vote of the Corporate Members resident therein?"

Mr. Castle.—I move the adoption of Question No. 3.

Mr. Hewes.—My suggestion was that they be read in conjunction with the numbers.

The President.—I think that is all right, but the motion was put and carried; and it would not do any good now if I read it.

Mr. Hewes.—If a motion is in order that such reference be read in full with each section, I move that those sections be read.

(Motion seconded.)

The President.—You mean all of them.

Mr. Hewes.—Each one referred to under each question.

Mr. Hansel.—Every one has them before him.

A Member.—I rise to a point of order. There is a motion before the house.

The President.—I do not think there is any objection. It will only take two or three moments. Question No. 1 has been acted upon. I will read the balance of it: "Division A, Sections 1-5, pages 4-6". That is No. 1. Question No. 2 has in brackets, "Division B, Section 1, a, b, c, and h, page 6." Question No. 3: "Division B, Section 1, e, f and g, page 6." Two of them are acted upon. The question is now as to the third.

(Cries of "Question".)

The President.—All in favor of the Question No. 3 please say "aye"; contrary, "no". Carried.

Mr. Hansel.—I move the adoption of Question No. 4 under Section B.

(Motion seconded.)

The President.—You have heard the motion that we now take up Question No. 4: "Shall a portion of the Society's dues be allowed to local sections? (Division B, Section 1, i, page 6)." All in favor please say "aye"; contrary, "no". Is there no more discussion?

(Motion carried.)

Mr. Castle.—I move the adoption of Question No. 5.

(Motion seconded.)

The President.—The motion is to adopt No. 5, which reads as follows: "Shall the present Nominating Committee be abolished and candidates for the offices of President, two Vice-Presidents and Treasurer be nominated by representatives of local sections in annual conference? (Division B, Section 1, j and k, pages 6-7)."

(Cries of "Question".)

All in favor please say "aye"; contrary, "no". There do not appear to be any "noes" at all.

(Motion carried.)

Mr. Castle.—I move the adoption of Question No. 6.

(Motion seconded.)

The President.—It is moved and seconded that we adopt No. 6: "Shall the dues of all Non-resident Members above the grade of Junior

be increased to provide for greater activities of the Society, but not to exceed $5.00 per annum".

J. C. TRAUTWINE, JR., ASSOC., AM. SOC. C. E.—It would be in very bad taste for me, as a Non-resident Associate, to object to an attempt to reduce my dues from $10.00 to $5.00; but I cannot think that that is the intent of the question.

MR. HUMPHREY.—Be increased.

MR. TRAUTWINE.—To not exceed $5.00.

THE PRESIDENT.—I rather think you are right.

C. D. THOMAS, ASSOC. M. AM. SOC. C. E.—I move an amendment that it read "shall not be increased over $5.00".

MR. HUMPHREY.—I accept that—shall be increased not to exceed $5.00 per annum.

THE PRESIDENT.—I shall have to have a written, new question, showing just what that means.

MR. HUMPHREY.—May I say that I offer a motion in deference to the gentleman whose sensibilities were wounded by the possible reduction of his dues, that we add after the word "but" in the last line "said increase not to exceed $5.00 per annum".

(Motion seconded.)

THE PRESIDENT.—Suppose you wanted a little more money—you could not increase it at any time. You are fixing this for all time, it seems to me; but I did not do it.

(Cries of "Question".)

The question before the house is No. 6: "Shall the dues of all Non-resident Members above the grade of Junior be increased to provide for greater activities of the Society, but said increase not to exceed $5.00 per annum?"

THE SECRETARY.—The word "but" comes out.

THE PRESIDENT.—It will not hurt it any to leave it in. All in favor of that motion please say "aye"; contrary, "no". Carried.

MR. CASTLE.—I now move the adoption of Mr. Humphrey's resolution as a whole.

(Motion seconded.)

MR. KEITH.—I move an amendment to the motion just made by the addition of a further resolution: "And it is further resolved that the Board of Direction may add such other questions or amend the form or wording of the questions as given above, by such supplementary questions as in their judgment are considered wise".

MR. WILLIAMS.—I rise to a point of order. That amendment is absolutely unnecessary, the Board can do it anyway; and it is an insult to the Board for us to tell them they may.

MR. KEITH.—It has been stated that the wording of the questions as presented should not be changed one iota. Now, it seems to me that that would be very unwise, and therefore I offered the resolution which

I did; and I think it will be for the best interests of all if this resolution, or something covering the same point, should be carried.

The President.—I doubt if a resolution of that kind——

Mr. Talbot.—I think this ought to be cleared up in some way. We have in the record two different statements, some of them from the same members, to the effect that these questions are not to be changed one iota, and the other to the effect that they may be changed if it be considered necessary. Which is to be taken as the action of this meeting?

F. J. Sprague, M. Am. Soc. C. E.—Additions, not changes.

Mr. Humphrey.—May I state, as the mover of these resolutions, that these questions were not to be changed if approved by the Meeting; but it was not intended that they should prevent the Board of Direction from adding such additional questions to be sent out as it may deem necessary.

The President.—I think it is perfectly proper——

Mr. Castle.—The question before the house is that the resolution of Mr. Humphrey be adopted as a whole.

(Motion seconded.)

Mr. Rights.—I believe the time was specified when the Board of Direction must send out these questionnaires. I think it was stated as February 9th.

Mr. Humphrey.—Yes.

Mr. Rights.—It seems that the Board in preparing other questionnaires was not preparing any explanatory statements, because the statement had been made to the effect that that could not be done. You have just listened to the proposed nomination of a new Committee to consider this; and it seems to me that you have given this new Committee a very limited time for its work. It seems to me that the time limit ought to be advanced, especially as the Annual Convention will not occur until October, and no action relative to changes in the Constitution can be taken up until that time.

Mr. Humphrey.—I do not take it for a moment that the questions are going to amend the Constitution. I understood the Secretary to say that they could not probably be reached until October, but the first step is to find out the temper of the Society, whether they want such amendments made to cover these things. The great difficulty in our Society is delay and debate. I submit that the questionnaires can be just as well sent out and prepared in the time stated as if you waited six months. We have the other Societies to consider. The mechanical and electrical engineers are ready. Other Societies are ready. The Engineers' Club of Philadelphia has adopted this plan. The Washington Society of Engineers has adopted this plan. The Minnesota Joint Board has adopted this plan. Why should the Society be forever holding up these resolutions for more time?

THE PRESIDENT.—Let me say that the time is quite short to get this thing ready, and get it printed and sent out. It is a fact, as Mr. Rights says, suppose these are sent out, they are merely answers, they could not be presented to any meeting until October anyway; but, in the first place, you tie us up to a short time in February to send them out; and if they are approved as a whole they have to be sent out at that time, no matter what happens.

MR. HUMPHREYS.—May I ask Mr. Humphrey if he would think it wise in the interest of the reform, a large measure of which I am thoroughly in favor of, to extend the period a little, so that the Secretary would be willing to say that it can be done?

MR. HUMPHREY.—I would be willing to extend it one week.

MR. METCALF.—It seems to me that in order that there may be no division of opinion as to the proper interpretation of the action of this Meeting, and to give voice to the present sentiment, it would be desirable to put on record the resolution in regard to the authority of the Board. It does not seem to me that it implies any discourtesy to the Board. The resolution that was offered seems to me a good one except in one respect, that in its verbiage it referred to the foregoing resolutions.

Now, it seems to me that the authority ought to be a little broader than that; and I have framed the following motion which I should like to offer in substitution, which I think is in conformity with the spirit of the statement which has just been made by Mr. Humphrey:

"Moved that the Board of Direction be authorized to prepare and send out to the membership such additional questions as may appear to it necessary to give the fullest opportunity for the expression of the opinions of the membership upon the objects sought, the proposals submitted and that may be submitted, and their alternates."

A MEMBER.—I second the amendment as proposed by Mr. Metcalf.

MR. HUMPHREY.—I hope Mr. Metcalf will not press the motion until afterwards. I shall be glad to second it, but I think that is a separate matter.

MR. METCALF.— I am content to withdraw it until later.

MR. RIGHTS.—I see the possibility of two sets of questionnaires: one set already prepared by Mr. Humphrey, which will go out to the membership on the day specified, and another set which might be prepared by the new Committee of the Board, after they had opportunity to study it; and it seems to me that that would be very unhappy. My suggestion would be—I don't know that I want to offer it as an amendment, but a suggestion to Mr. Humphrey that he take off that time limit.

MR. HUMPHREY.—No, I want to make it clear that I accept one week's extension; make it February 16th for the date the questionnaires are to be sent out; to be canvassed on March 8th and March 23rd; not earlier than March 8th, nor later than March 23rd.

MR. WILLIAMS.—Mr. Chairman, in reply to Mr. Rights I would like to say that it seems to me that it might be very wise if these questions went out to the membership before the other questions were ready. The membership might vote them all down, and then it would not be necessary to send out any more.

THE SECRETARY.—These dates would bar quite a percentage of the membership from voting on a very important matter before the Society. I do not know exactly what it is now, but about 9 or 9½% of the membership of this Society live in foreign countries. It does seem to me that a longer time should be allowed between the sending out of the questionnaire and the receipt of the final count on the ballot, because the real question is the time of getting it out, and not the time of counting it.

MR. HUMPHREY.—May I ask Dr. Hunt what he thinks would be the time needed?

THE SECRETARY.—I think about fifty days.

MR. HUMPHREY.—From the time the questionnaire went out?

THE SECRETARY.—Yes, sir.

MR. HUMPHREY.—Isn't that a long time?

THE SECRETARY.—That is the rule that we adopt in sending out our preliminary list of members, so that all our members can have an opportunity to write back about candidates.

MR. HUMPHREY.—It has to go part of the way around the world to get to some of the members; isn't that a small percentage?

THE SECRETARY.—It is rather small, but quite a number of them, I think, would not have an opportunity——

MR. HUMPHREY.—Is there any place where ten days would not reach any member?

THE PRESIDENT.—There are a great many members, I think, Mr. Humphrey, who do not get their mail quite as quickly as some others.

THE SECRETARY.—I only make that point because the point has been raised by members of the Society who live in those places that the ordinary time for balloting, even for officers, is sometimes too short for them to get in their votes.

J. H. GRANBERY, M. AM. SOC. C. E.—I would like to say that I have myself been obliged to cable word to the Society in order to get it there in time for action.

MR. HUMPHREY.—If the Secretary states that fifty days is the rule of the Society, I, for one, do not want to violate that rule. If the other gentlemen here are ready to accept February 16th as the time when the questionnaire must go out, that it must be canvassed within fifty calendar days—I think, in order that this may be earlier, that the dates be changed to read as follows: I offer this as an amendment, that the above be sent out on or before February 16th, and that it be canvassed not later than fifty days thereafter, or earlier than March 15th.

Mr. Castle.—I believe I seconded the original resolution. I accept that amendment.

Mr. Davis.—That does not comply with the rule. That does not give fifty days for the correspondence.

Mr. Humphrey.—It is a question of machinery.

The Secretary.—I should say not earlier than fifty days and not later than sixty days.

Mr. Humphrey.—All right, sir. I bow to that decision.

The President.—The question is on the vote on the report as a whole. All in favor please say "aye". Contrary, "no". It is voted.

Is there any gentleman who has new business to present?

Mr. Metcalf.—I move you that the Board of Direction be authorized to prepare and send out to the membership such additional questions as may appear to it necessary to give the fullest opportunity for expression of the opinions of the membership upon the objects sought, the proposals submitted and that may be submitted, and their alternatives.

Mr. Humphrey.—I second the motion.

G. Aertsen, M. Am. Soc. C. E.—In view of what Mr. Williams said about that being superfluous, would it not be better to use the word "requested" instead of "authorized" if the Board of Direction can do it without our authority?

Mr. Metcalf.—All right, I substitute that word "requested".

The President.—You have heard the motion. All in favor please say "aye"; contrary, "no". Motion carried.

Mr. Sprague.—Mr. Chairman, at a meeting of the American Institute of Consulting Engineers, I was appointed by the Chairman one of a Committee of three, the other two members being Mr. Cooley and Mr. Whinery, to present the fact that a certain resolution had been passed, and to ask co-operation on the part of this Society in an important matter. You gentlemen that are going out, I am going to ask you to postpone your going out for five minutes on a matter of National importance to everybody, and particularly to engineers.

This Society today, at its Annual Meeting, has expressed briefly in no uncertain terms the necessity of getting out of the leading strings in which we have been, of getting away from the narrow Engineering and Professional view which has so long governed our action, to get away from that righteous complaint which we have heard made, that engineers have had no voice, but only lawyers, in the framing of legislation and the passing thereof.

Many of the members of this Society have served in the fighting forces of the United States in this last great war; and I think that that war has aroused the conscience and broadened the views of men so that they are more willing to take part in the public and civic affairs of this country.

Today we are in the presence of a very great danger of demoralization to the fighting forces of the country in the Navy and in the Army. That is particularly illustrated by two very patent facts. Nearly 2 500 regular officers of the Army, and nearly 500 regular officers of the Navy, to say nothing about the reserve officers and very many thousands of skilled and enlisted men of the Navy, have resigned, or terminated their connection. Every battleship we send out from this country goes incompletely manned. The flagship *Pennsylvania* left the Port of New York with a crew of 1 100 men, of which over 50% were boys under 18 years old, without the slightest knowledge of maritime or naval affairs.

Now, the great trouble has been the lack of proper compensation of officers and men. Officers and men today are being paid at the rate they were paid before the war. They do not belong to unions. The laws of their profession, self-pride, prevents their acting as a unit on anything that affects their pay or their compensation. But every man here knows that the very things that affect your living and mine, affect in a greater degree the living of officers who are shifted from place to place, as military and naval officers are. As a matter of fact, they are placed in a situation of very great and general distress, which is demoralizing the Services.

There has been an attempt to correct this, and there are before Congress two bills looking in some way to ameliorate this condition. To my mind it is a necessity for the people of this country to maintain at the very highest state of efficiency the fighting forces of the country. Some time ago I was in correspondence with Floor Leader Mondell—and I have had a great deal of experience in an altruistic way in trying to secure aid for the military and naval service of this country. I want to express the opinion that both in Albany and Washington, before the House of Representatives and before the Senate, I have been received with courtesy, partly because I was an engineer, but principally because I was representing the United States Consulting Board. I have been received with a courtesy which was very satisfactory and encouraging to the engineers who are inclined to take interest in public affairs.

In talking with Mr. Mondell, he made the statement that it was necessary to curtail the expenses of the country. I said to him, "Mr. Mondell, I quite agree with you, but you are in no different position as the Floor Leader of this House than any other Floor Leader has been in, to serve well your party, to show unity and efficiency in the promotion of bills in the House, to conduct public business precisely as a private business or a family budget is conducted; and that when cutgo becomes greater than income, to cut capital expenditures, wipe out shallow pools, change rapids into navigable streams and supply public buildings for the winning of votes; but there is one thing you cannot do, and that is sacrifice the efficiency of that on which this

country depends, and which has cost this country so many billions of dollars."

I found that I was the only civilian in the United States outside of Congress that took the trouble to go to Washington to help that measure. I went there out of a pure desire to do something to return to the Government of the United States the obligation which I had received in being educated as a Naval Officer before I went into civil life. It cost me some time and some money, but it is a great deal of satisfaction; and I do not think any man has ever received a warmer series of letters, a more appreciative series of letters, from Naval Officers than I have received, to express the thoughts in their minds of gratitude that anybody in civil life would take the trouble to show an interest in the United States Navy.

I do not know how many of you have brothers or fathers or sons that have been in the service either afloat or abroad; but those of you who have will have a spirit of satisfaction in what they have done; and no one who is an efficient engineer can desire to see any deterioration in that which has been built up.

The Naval Consulting Board, some time ago, when I appeared before it in Washington—this Board is made up entirely of engineers—passed unanimously a resolution favoring an increase in the compensation of officers and enlisted men for the five Services, the Army, the Navy, the Marine Corps, the Coast Guard and the Public Health Service. And day before yesterday the American Institute of Consulting Engineers passed a similar resolution; and I promised to bring it to your attention and to request your co-operation and the co-operation of the other Societies; and I take the liberty of calling your attention to one or two facts.

I do not suppose that there is to-day afloat anywhere in the world a more complicated piece of mechanism than a modern battleship. It is not only a ship, it is a transport, a cruiser, a battery, a hotel, a great social organization, and it carries the honor of the country; and there are no men in our Government service who have a greater demand upon them, or a greater responsibility than our Naval Officers and men.

Mr. Davis.—Mr. Chairman, I see some of the members of the Board are leaving. I would like to announce that immediately upon the adjournment of this meeting the new members of the Board of Direction take office and the Board is requested to meet immediately in the Board Room on the adjournment of this meeting.

Mr. Sprague.—To get through with what I have to say, I want to offer the following resolution for action at this meeting. It is in the spirit of what has already been said here—the desire to take part in public affairs. I think it is our duty as citizens to support what is going on in Washington.

Whereas: The members of the Society note with increasing concern the threatened break-down of the morale and efficiency of the military and naval establishments of the country, a fact emphasized by the large number of resignations of regular Army and Navy Officers, the lack of re-enlistment of skilled men and the sending to sea of undermanned fleets—all imperilling national safety at a time of world unrest; and

Whereas: We believe this condition is largely due to that short-sighted policy which has denied to officers and men of both Services proper recognition of their loyal and devoted work in the late war, and has thus far refused them compensation commensurate with that demanded by and paid to civilians of like ability and comparable responsibilities; be it

Resolved: That the American Society of Civil Engineers recognize and appreciate in the highest degree the unselfish devotion of our fighting forces ashore and afloat at a time of great national emergency; and in order that their morale and efficiency may be maintained in the highest degree and our National safety conserved against any emergency, strongly urge upon their representatives in Congress the imperative need and duty to make such provision for increases of compensation as shall meet the changed plane of life and the increased costs of living; and specifically urge that without delay there shall be passed a bill therefore which shall be in its terms at least as favorable as those in Wadsworth bill, S. 3383, for increasing the pay and allowances of the commissioned and enlisted personnel of the Army, Navy, Marine Corps, Coast Guard and Public Health Services; and be it

Resolved: That a copy of these resolutions be transmitted to the Secretaries of War, the Navy and the Treasury, the Chairmen of the Senate and House Military and Naval Committees, and the floor Leader of the House; and be it

Resolved: That a copy of these resolutions be also transmitted to the Engineering Council and to the three National Engineering Societies.

MR. WILLIAMS.—I second that motion.

MR. SWAIN.—Might I ask Mr. Sprague if he would let us know what the total increase in expense is estimated to be?

MR. SPRAGUE.—Yes, sir, if the Wadsworth bill is passed, I have the present assurance of a member of the House Naval and Military Affairs Committee that it will mean a maximum increase of about 31 per cent. Our cost of living has increased about 80 or 85 per cent. The officers are modest in their demands; and it includes a provision, if things go down, making it possible for the Government to decrease that. I will tell you what it means for the entire Army and Navy, commissioned and warrant officers, active and retired, and for all enlisted men except those of the first grade of enlisted men—it is one cent per week per inhabitant of the United States. Are they worth it, or are we?

MR. SWAIN.—What is the total, Mr. Sprague?

MR. SPRAGUE.—About \$56 000 000.

Mr. Gideon.—I would like to amend this motion by including the civil engineers employed in the War Department and in the Navy.

Mr. Rights.—I am entirely in sympathy with the campaign; but it seems to me a bad precedent for those present to commit the entire Society.

Mr. Sprague.—Those assembled at an Annual Meeting in New York City.

Mr. Herschel.—I would like to call Mr. Sprague's attention to the fact that Engineering Council meets tomorrow, and represents the four Founder Societies, and ask him if he would not rather have this resolution before the four Founder Societies than before only one of them.

Mr. Sprague.—Before each one of them individually.

The President.—Gentlemen, you have heard the motion. All in favor say "aye"; contrary, "no". Carried.

F. W. Scheidenhelm, M. Am. Soc. C. E.—I want to propose a resolution directing the Board of Direction of the Society to appoint a Committee on Water Power Development. This is probably a propitious year for water power development, and yet the fact that a bill has passed the United States House, and has passed the United States Senate, and is now in conference, even assuming that the bill comes successfully through Congress, and receives the approval of the President, will not mean that water power development will go ahead as it should. It takes more than that.

It takes an educated public policy. The sale of securities to the public is necessary if development is to go ahead, for, in general, it is the public that furnishes the money. Bankers will not take securities for new projects unless there is a demand on the part of the public for them. In that the Engineering Profession, and in particular the Civil Engineering Profession, can be of great service.

Aside from the provision of Federal legislation there is the question of State legislation, involving streams that are not navigable, and streams that are not on public lands. There is much to be done in regard to States. There is West Virginia with a law that needs to be amended. New York State is floundering around without any water policy.

There is this one other feature I will touch on, and that is the fact that the electrical engineers are now in the forefront of this movement that is gradually growing for increased water power development. You all know that in water power development about 75% of the work is Civil Engineering; about 25% is Electrical Engineering. How much of the talk of water power work comes from civil engineers? Mostly you will find it is the electrical branch of the profession.

I think it is entirely in accord with the policy as evidenced by this meeting, one for advance, one to make the Society of greater public

utility, to come more to the forefront to take its proper place. I therefore move that it is the sense of this meeting that the Board of Direction appoint a Special Committee on Water Power Development.

(Motion seconded and carried.)

Mr. Davis.—The hour has arrived for the adjournment of this meeting. After adjournment the Board of Direction is requested to meet immediately on the 15th floor in the Board Room.

(Adjournment is moved and seconded.)

The President.—All in favor of the motion to adjourn, please say "aye"; contrary, "no". Carried.

Meeting adjourned.

EXCURSIONS AND ENTERTAINMENTS AT THE SIXTY-SEVENTH ANNUAL MEETING

Wednesday, January 21st, 1920.—After the Business Meeting, lunch for about 750 members was served in the meeting room on the 5th floor.

At 9 P. M. the Reception to the President was held on the 15th floor of the Engineering Societies Building, with dancing after 9.30 P. M. on the 5th floor. There was an attendance of about 300. Supper was served after 11 P. M. in the rooms of the Society on the 15th floor.

Thursday, January 22d, 1920.—The day was devoted to an excursion to the Port of Embarkation of the United States Army at Hoboken, N. J., and the Brooklyn Navy Yard.

About 500 members and guests assembled at Pier 3 at 10.30 A. M. and were assigned in parties to the guides detailed by Maj.-Gen. David C. Shanks, U. S. A., Commanding General, through whose courtesy the visit had been arranged. In a most interesting address describing the activities of the Port, Maj.-Gen. Shanks mentioned the fact that 17 years ago to a day the members of the Society had visited the same piers, then just reconstructed after the great Hoboken fire. Gen. Shanks had a copy of the programme then issued to the members. After visiting the piers and the post office for soldiers' mail, the United States Army Transport *President Grant* was inspected—a ship built at Belfast, Ireland, in 1907, for the Hamburg-American Line, which was interned and taken over in the fall of 1917, and which transported nearly 40 000 troops; with a crew of 305 officers and men, the total troop capacity was 5 000.

Through the courtesy of the Emergency Canteen Service of the American Red Cross, an Army luncheon was served at noon in the same manner in which 2 500 000 soldiers were served going to and coming from the War. Mess kits were issued as the members formed in line and passed by the Red Cross workers in their regulation uniforms.

A resolution of thanks to Maj.-Gen. Shanks, his officers and the Red Cross workers, was unanimously carried, and three rousing cheers were given for the members of the Hoboken Unit and Mrs. Van Ingen's Unit of the Red Cross.

At 1.15 P. M. the party embarked by ferry for the United States Navy Yard at Brooklyn, N. Y., passing around the Battery, and viewing Governors Island, the East River docks and the bridges connecting New York and Brooklyn.

Arriving at the Brooklyn Navy Yard, the party was divided into small groups, under the guidance of Navy Officers, and the two new ship ways in process of construction, the new Structural Steel Shop

and Mould Loft, the Forge Shop, the Boiler and Machine Shop, the Boat Shop, the Power House, the Light Machine Shop, and the four dry docks were inspected.

The parties were conducted through the U. S. S. *Tennessee,* a 34 000-ton electrically driven battleship mounting twelve 14-in. guns in four turrets. Although it was the center of the greatest construction activity, in an endeavor to complete it for commission about February 1st, the members were given every opportunity to inspect details.

At 8.30 P. M. an informal smoker was held on the 5th floor of the Engineering Societies Building, at which about 580 members and guests were present. During the evening, at an informal meeting presided over by President Davis, a resolution* expressing the feeling of those present in regard to the retirement of Chas. Warren Hunt as Secretary was unanimously adopted.

The following list contains the names of 923 members of various grades who registered as being in attendance at the Annual Meeting. The list is incomplete, as some members failed to register, and it does not contain the names of any of the guests of the Society or of individual members. It is estimated that the total attendance was about 1 175.

Abbott, C. P......Elizabeth, N. J.
Abbott, H.........New York City
Adams, A........Brooklyn, N. Y.
Adams, E. G.......New York City
Aertsen G.......Philadelphia, Pa.
Aiken, W. A..Mamaroneck, N. Y.
Alexander, H. J., White Plains, N. Y.
Alison, T. H.....Bayonne, N. J.
Allen, E. Y......New York City
Allen, F. W....Mt. Vernon, N. Y.
Allen, K.........New York City
Alvord, J. W........Chicago, Ill.
Ammann, C. H., South Amboy, N. J.
Andrews, H. S.....New York City
Archer, A. R......New York City
Armstrong, R. W.Waltham, Mass.
Ash, W. J........Brooklyn, N. Y.
Ashbaugh, L. E...New York City
Ashley, C........Honeoye, N. Y.
Atkinson, A.New Brunswick, N. J.
Atkinson, G......New York City
Atwater, H. C....New York City
Atwood, T. C.....Baltimore, Md.
Auryansen, F.....Jamaica, N. Y.
Austin, W. E....New York City
Averill, F. L...Washington, D. C.

Babcock, W. S.....New York City
Backes, W. J..New Haven, Conn.
Baker, F. A........Newark, N. J.
Baker, P. S.....Philadelphia, Pa.
Balcom, H. G.....New York City
Baldwin, A. S.......Chicago, Ill.
Baldwin, W. J...New York City
Balleison, L. L..Brooklyn, N. Y.
Ballinger, W. F..Philadelphia, Pa.
Bamford, W. B.....Belmar, N. J.
Baptiste, E. E..Jersey City, N. J.
Bard, G. P......Youngstown, O.
Bardol, F. V. E.....Buffalo, N. Y.
Barnes, F. E......New York City
Barnes, O. F...Jersey City, N. J.

* See page 140.

Barney, S. E..New Haven, Conn.
Barney, W. J......New York City
Barry, E. J......Camp Dix, N. J.
Bassett, H. H...Worcester, Mass.
Bassett, W. M...Worcester, Mass.
Baucus, W. I.North Adams, Mass.
Baum, G.........Yonkers, N. Y.
Baylis, R. S....Huntington, N. Y.
Beahan, W.........Cleveland, O.
Bean, E. D...White Plains, N. Y.
Bean, G. L....Philadelphia, Pa.
Beer, F. M......Brooklyn, N. Y.
Beerbower, D.....New York City
Beggs, G. E......Princeton, N. J.
Belcher, W. E....New York City
Belden, E. T....Englewood, N. J.
Belden, H. A......New York City
Belknap, J. M....New York City
Bellows, S. R.......Boston, Mass.
Belzner, T.......Brooklyn, N. Y.
Benedict, F. N.East Orange, N. J.
Bensel, J. A......New York City
Benson, O........New York City
Bentley, J. C....Elizabeth, N. J.
Berger, J........ New York City
Berle, K..........New York City
Besselievre, E. B.Philadelphia, Pa.
Beswick, J. E.,
New Brighton, N. Y.
Bettes, C. R..Far Rockaway, N. Y.
Betts, R. T.......New York City
Beugler, E. J.....New York City
Binckley, G. S..Los Angeles, Cal.
Bird, H. C..........Chester, Pa.
Bixby, W. H........Chicago, Ill.
Black, W. M...Washington, D. C.
Blackwell, P. A....Roanoke, Va.
Blakeslee, C. B.New Haven, Conn.
Blakeslee, H. L.New Haven, Conn.
Blanchard, A. H.Ann Arbor, Mich.
Blanchard, M........Chicago, Ill.
Blanchard, R. K..New York City
Boardman, C. S....Buffalo, N. Y.
Boardman, H. S.......Orono, Me.
Boardman, H. E..New York City
Boardman, W. H...Newark, N. J.
Bodycomb, W. C..New York City
Boes, F. C....East Aurora, N. Y.
Bogart, J.........New York City
Bogert, C. L......New York City
Boller, A. P., Jr.,
East Orange, N. J.
Bontecou, D..Mamaroneck, N. Y.
Boorman, K. M....New York City
Booth, G. W.....New York City
Borough, E. W....New York City
Boughton, W. H.,
Poughkeepsie, N. Y.
Bowen, E. W....Philadelphia, Pa.
Bower, C. P....Germantown, Pa.
Brace, J. H......New York City
Brackenridge, J. C.New York City
Bradley, F. E.....New York City
Breed, H. E......New York City
Breitzke, C. F....Boonton, N. J.
Brennan, E. M....Albany, N. Y.
Brennan, J. G......Albany, N. Y.
Brennan, J. L....New York City
Breuchaud, J.....New York City
Briggs, W. C....Brooklyn, N. Y.
Brinckerhoff, A. G.,
Brooklyn, N. Y.
Bringhurst, J. H.Philadelphia, Pa.
Brodie, O. L.,
West New Brighton, N. Y.
Brooks, D. W....New York City
Brown, B. S........Boston, Mass.
Brown, L. F.....Brooklyn, N. Y.
Brown, N. F....Philadelphia, Pa.
Brown, T. E......New York City
Brown, W. E.....New York City
Brown, W. N..Washington, D. C.
Brownell, L. D......Utica, N. Y.
Brush, W. W....New York City
Bryan, C. W.....New York City
Buck, H. R......Hartford, Conn.
Buck, R. S.......New York City
Budd, P. H......Summit, N. J.
Buehler, W..........Chicago, Ill.
Buettner, O. G....New York City

Burr, W. H.......New York City
Burroughs, H. R..New York City
Burrowes, P..........Russell, Va.
Burton, W.......Montclair, N. J.
Bush, A. L......Philadelphia, Pa.

Cadwallader, W. L.New York City
Campbell, C. C..Philadelphia, Pa.
Campion, H. T..Philadelphia, Pa.
Canaga, G. B...Philadelphia, Pa.
Carmalt, L. J..New Haven, Conn.
Carpenter, F. W.Wilmington, Del.
Carpenter, S. T. M..Buffalo, N. Y.
Carr, A.......East Orange, N. J.
Case, J. F........New York City
Castle, S. N..New Rochelle, N. Y.
Castleman, F. L....Pencoyd, Pa.
Chadbourn, W. H.New York City
Chambers, R. H...New York City
Chase, C. F..New Britain, Conn.
Chase, C. E.......New York City
Chase, G. H....Fitchburg, Mass.
Chase, J. C..Derry Village, N. H.
Cherry, A. G....Worcester, Mass.
Chester, J. N.....Pittsburgh, Pa.
Chorlton, W. H...New York City
Christian, G. L....Yonkers, N. Y.
Christie, W. W..Ridgewood, N. J.
Church, E. C.....New York City
Churchill, J. C....Oswego, N. Y.
Clark, A. E......New York City
Clark, G. H......New York City
Clarke, E. W......Baltimore, Md.
Clarke, G. C......New York City
Clarke, St. J.......Bogota, N. J.
Class, C. F......Harrisburg, Pa.
Closson, E. S....Montclair, N. J.
Clow, P.........New York City
Cobb, L. R........New York City
Codwise, H. R....Brooklyn, N. Y.
Coffin, T. de L....Katonah, N. Y.
Cole, C. L........Meriden, Conn.
Cole, H. J........Ossining, N. Y.
Cole, H. O.......New York City
Coleman, J. F...New Orleans, La.

Collier, B. C......Allentown, Pa.
Collins, T. E.....Elizabeth, N. J.
Conant, L. C......Allentown, Pa.
Conard, W. R...Burlington, N. J.
Conger, A. A....Worcester, Mass.
Connelly, J. A....New York City
Constant, F. H...Princeton, N. J.
Conway, J. S...Washington, D. C.
Cooley, M. E...Ann Arbor, Mich.
Coombs, A. W.....New York City
Coombs, S. E.....New York City
Cooper, S. W.....Trenton, N. J.
Cox, W. J....New Haven, Conn.
Coyne, H. L......Brooklyn, N. Y.
Craig, R. H....Washington, D. C.
Craigmile, C. J....Midvale, N. J.
Crane, A. S.......New York City
Craven, A. S....Philadelphia, Pa.
Creager, W. P....New York City
Cresson, B. F., Jr..New York City
Creuzbaur, R. W..New York City
Critchlow, H. T...Trenton, N. J.
Crocker, H. S....New York City
Crook, J. A........Denver, Colo.
Crooks, C. H....New York City
Cross, W. C......Brooklyn, N. Y.
Crowell, F. S....New York City
Cuddeback, A. W..Paterson, N. J.
Cullen, J. F.....Philadelphia, Pa.
Culyer, T. C....New York City
Cummings, R. A..Pittsburgh, Pa.
Curtis, C. E........Ithaca, N. Y.
Curtis, F. S........Boston, Mass.

Dahm, S.........New York City
Dakin, A. H., Jr..New York City
Danforth, G. C.....Augusta, Me.
Davies, J. P......New York City
Davies, J. V......New York City
Davis, A. P....Washington, D. C.
Davis, B. H......New York City
Davis, C.........New York City
Davis, J. L.,
Manchester Center, Vt.
Davison, G. S.....Pittsburgh, Pa.

Dawley, W. M. . Rutherford, N. J.
Day, C. I. . . . . Troy, N. Y.
Delson, I. . . . Staten Island, N. Y.
Demarest, I. . . . . . Madison, N. J.
Dennett, R. C. . . . New York City
Develin, R. G. . . Philadelphia, Pa.
Devlin, H. S. . . . . . Brooklyn, N. Y.
Dewey, C. L. . . . . . Allentown, Pa.
De Witt, P. H. . . . . Newark, N. J.
Diamant, A. H. . . . New York City
Dickerson, O. H. . . . Duluth, Minn.
Dillenbeck, C. . . . Philadelphia, Pa.
Dimon, D. Y. . . . . New York City
Dirats, J. K. . . . . . . Paris, France.
Disbrow, C. A. . . . New York City
Donham, B. C. . . . New York City
Doron, C. S. . . . . . Brooklyn, N. Y.
Dorrance, W. T.
New Haven, Conn.
Doten, L. S. . . . Washington, D. C.
Doyen, G. E. . . . . . New York City
Doyle, J. S. . . . . . . Baltimore, Md.
Drane, B. S. . . . . . Charlotte, N. C.
Dresser, G. L. . . . New York City
Drew, C. D. . . . . . . New York City
Drummond, W. W.,
Fort H. G. Wright, N. Y.
Duckwall, A. E. . . . Scottdale, Pa.
Dufour, F. I. . . . . . . Boston, Mass.
Dunham, W. R., Jr,
New Haven, Conn.
Durant, A. . . . . . . New York City
Durham, H. W. . . . New York City
Durham, L. . . . . . Scarsdale, N. Y.
Dutton, C. H. . . . Providence, R. I.
Dykeman, C. F. . Brooklyn, N. Y.

Earle, T. . . . . Bethlehem, Pa.
Easby, W., Jr. . . Philadelphia, Pa.
Eddy, H. P. . . . . Boston, Mass.
Eden, A. W. A. . . . New York City
Edwards, D. G. . . . Jamaica, N. Y.
Edwards, J. H. . . . New York City
Edwards, W. R. . . . Baltimore, Md.
Eide, T. . . . . New York City
Elcock, C. . . . . Elizabeth, N. J.
Elton, H. C. . . . Bridgeport, Conn.
Elwell, C. C. . . . New Haven, Conn.
Emerson, F. C. . . . Cheyenne, Wyo.
Endemann, H. K. . Jamaica, N. Y.
Everett, M. R. . . . . Newark, N. J.
Evers, R. . . . . New York City

Fairchild, J. F.,
Mount Vernon, N. Y.
Fairchild, S. E., Jr.,
Philadelphia, Pa.
Fairlie, J. W. . . . Providence, R. I.
Fales, A. L. . . . . Boston, Mass.
Farley, J. M. . White Plains, N. Y.
Farley, M. M. . . . New York City
Federlein, W. G.,
Rockville Center, N. Y.
Ferguson, L. R. . Philadelphia, Pa.
Files, T. H. . . . . . New York City
Fisher, E. A. . . . Rochester, N. Y.
Fitzgerald, W. E.,
New Brunswick, N. J.
Fitzmaurice, E. J.,
Philadelphia, Pa.
Fletcher, R. . . . . Nyack, N. Y
Focht, L. . . . . Trenton, N. J.
Fogg, R. J. . . . . . . Bethlehem, Pa.
Follin, J. W. . . . Philadelphia, Pa.
Forbes, F. B. . . . . . New York City
Ford, F. L. . . . New Haven, Conn.
Ford, H. C. . . . . . . New York City
Ford, W. H. . . . Philadelphia, Pa.
Forrest, C. N. . . . . . Maurer, N. J.
Foss, F. E. . . . . New York City
Foster, E. H. . . . . . New York City
Fougner, N. K. . . . New York City
Fox, E. F., Jr. . . . Brooklyn, N. Y.
Fowler, C. E. . . . . . New York City
Fowler, C. W.,
Spuyten Duyvil, N. Y.
Fox, E. F., Jr. . . . Brooklyn, N. Y.
Fox, W. F. Rockville Center, N. Y.
Francis, H. N. . Providence, R. I.
Frank, G. S. . . . Laurel Hill, N. Y.

Franklin, B.....Philadelphia, Pa.
Fraser, C. E.......New York City
Fraser, E. A......New York City
Freeman, M. H..New York City
French, A. W..Worcester, Mass.
French, H........New York City
French, J. B......New York City
French, O. B...Washington, D. C.
Frost, G. S......Philadelphia, Pa.
Fuller, A. H........Easton, Pa.
Fuller, G. W......New York City
Fuller, M. E......New York City

Gale, C. S............Dover, Del.
Gamsu, F. C......New York City
Gandolfo, J. H....New York City
Gardiner, J. de B. W., New York City
Gardner, H. C.....Lancaster, Pa.
Gardner, W......New York City
Garfield, C. A...Bronxville, N. Y.
Gaston, L. P......New York City.
Gatens, R. S.......Newark, N. J.
Gandell, D. S., Jr..Pottstown, Pa.
Gibbs, G..........New York City
Gideon, A..........Manila, P. I.
Giesting, F. A....New York City
Gifford. G. E....New York City
Gildersleeve, A. C.New York City.
Gilman, C........New York City
Glaeser, F.........Trenton, N. J.
Glover, P. H....Harrington, Me.
Goedecke, W.....New York City
Goldmark, H......New York City
Goldsborough, J. B., New York City
Goodell, J. M., Upper Montclair, N. J.
Goodman, S. S....New York City
Goodwin, R. E..Weehawken, N. J.
Gotwals, J. C....Norristown, Pa.
Gould, R. R......New York City
Gould, W. T., Hastings-on-Hudson, N. Y.
Graham, R. R....Yonkers, N. Y.
Granbery, J. H...New York City
Grant, J. R........Victoria, B. C.
Gravell, W. H..Philadelphia, Pa.
Gray, W..........New York City
Green, C. S......New York City
Greene, C........New York City
Gregory, C. E..East Orange, N. J.
Gregory, J. H....Baltimore, Md.
Groat, B. F......Pittsburgh, Pa.
Grove, W. G......New York City
Grover, N. C..Washington, D. C.
Gunby, F. M......Boston, Mass.
Gunther, C. O....Hoboken, N. J.

Hackenberg, J. O., Wilmington, Del.
Haefner, C. W..Mt. Vernon, N. Y.
Hager, A. B......New York City
Haggard, H. H..New York City
Hale, H. M......New York City
Hall, N. W......New York City
Halsey, W. H.Southampton, N. Y.
Hamilton, J. W...New York City
Hamilton, P. D. G., Needham, Mass.
Hammond, H. P..Brooklyn, N. Y.
Hanavan, W. L..New York City
Hanique, J. E., San Francisco, Cal.
Harby, I..........New York City
Hardesty, S....Kansas City, Mo.
Harding, H. S., Pelham Manor, N. Y.
Harding, R. S. San Antonio, Tex.
Haring, A........New York City
Harlow, G. R..Philadelphia, Pa.
Harris, B. B......New York City
Harris, S.......Philadelphia, Pa.
Harte, C. R....New Haven, Conn.
Harwi, S. J.......Bayonne, N. J.
Haskins, W. J....New York City
Hatch, F. N......New York City
Hauck, W........New York City
Hawgood, H....Los Angeles, Cal.

Hayford, J. F.....Evanston, Ill.
Hazen, A........New York City
Hazen, W. N......Orange, N. J.
Heiser, A. B....Brooklyn, N. Y.
Heiser, W. J....Brooklyn, N. Y.
Heller, J. W..South Orange, N. J.
Hellyer, H. A. C..Tenafly, N. J.
Henderson, A. R., Jersey City, N. J.
Hennebique, J. J., New York City
Henny, D. C......Portland, Ore.
Hermanns, F. E..Hoboken, N. J.
Herschel, C......New York City
Hewes, V. H....Bridgeport, Conn.
Hewett, B. H. M..New York City
Hewitt, G........New York City
Higgins, C. H....New York City
Higgins, J. W..New York City
Hildreth, J. L., Jr..Bayonne, N. J.
Hiles, E. K........Pittsburgh, Pa.
Hirst, A..........New York City
Hitchcock, F. C...New York City
Hjorth, L. R......New York City
Hodgdon, B. A., East Orange, N. J.
Hodgman, B. B..New York City
Hoerner, C. G....Phoenicia, N. Y.
Hogan, J. P......New York City
Hohl, A. K.....Philadelphia, Pa.
Holbrook, A. R....New York City
Holbrook, F. D......Decatur, Ill.
Holden, C. A..New Rochelle, N. Y.
Holden, C. A.....Hanover, N. H.
Holdredge, N. C..Laurens, N. Y.
Holland, C. M....Brooklyn, N. Y.
Hollyday, R. C....New York City
Hoover, A. P....Montclair, N. J.
Horton, T..........Albany, N. Y.
Hovey, O. E......New York City
Howard, E. H., Framingham, Mass.
Howe, C. E., Hastings-on-Hudson, N. Y.
Howell, W. A....Newark, N. J.
Howes, B. A......New York City
Howes, D. W......New York City
Hoyt, J. C....Washington, D. C.
Hoyt, W. A.........Altoona, Pa.
Hoyt, W. H........Duluth, Minn.
Hubbell, G. S......New York City
Hudson, C. W.....New York City
Hudson, H. W.....New York City
Hulbert, E. C....Pittsburgh, Pa.
Hulsart, C. R......New York City
Humphrey, R. L., Philadelphia, Pa.
Humphreys, A. C..New York City
Humphreys, E. S..New York City
Hunt, C. A......Brooklyn, N. Y.
Hunt, C. E......New York City
Hunt, Chas. Warren, New York City
Hunt, R. W..........Chicago, Ill.
Hunt, W. H......New York City
Hurd, H. L..White Plains, N. Y.
Hurlbut, C. C....New York City
Hutchins, E......New York City
Hyatt, C..........New York City
Hyde, H. E........Ithaca, N. Y.
Hyman, A. D....New York City
Hyman, H. A..Woodmere, N. Y.

Jackson, J. F..New Haven, Conn.
Jacobosky, G. G., Wilkes-Barre, Pa.
Jacobs, R. H......New York City
Jaques, J. D....Philadelphia, Pa.
Jarrett, E. S......New York City
Johannesson, S., Upper Montclair, N. J.
Johnson, A. N......Chicago, Ill.
Johnson, G. A..Washington, D. C.
Johnson, H....Middletown, N. Y.
Johnston, J. A., Springfield, Mass.
Johnston, J. H......Atlanta, Ga.
Jones, J........Philadelphia, Pa.
Jones, S. R.......New York City
Jordan, L. C..New Rochelle, N. Y.

Karner, W. J......New York City
Keefe, D. A..........Athens, Pa.
Keefer, C. H......Ottawa, Canada
Keith, H. C.......New York City
Kelly, H. A.......New York City
Ketcham, V. O..Wilmington, Del.
Ketchum, M. S..Philadelphia, Pa.
Khuen, R., Jr.....Pittsburgh, Pa.
Kienle, J. A......New York City
Kimball, F. C......Summit, N. J.
Kingsley, G.......New York City
Kinsey, W. A......Newark, N. J.
Kircher, P........New York City
Kirkwood, H. C...Flushing, N. Y.
Kittredge, G. W...Yonkers, N. Y.
Knickerbocker, C. E., New York City
Knight, E. K.....New York City
Knight, H. M.....Montclair, N. J.
Knighton, J. A....New York City
Knox, S. B.......New York City
Koch, E. L........Camden, N. J.
Kraus, A.......Glen Ridge, N. J.
Krause, M. C....Williamsport, Pa.
Krellwitz, D. W....Newark, N. J.
Kurtz, F..........New York City

Lamb, E. A........Albany, N. Y.
Lamson, W. M....Brooklyn, N. Y.
Lance, J. H.....Wilkes-Barre, Pa.
Landreth, O. H....New York City
Lang, P. G., Jr..Baltimore, Md.
Langthorn, J. S...New York City
Larsson, C. G. E., Plainfield, N. J.
Latimer, C. A...Elizabeth, N. J.
Lawrence, R. J...Philadelphia, Pa.
Lawton, F. T.....Jamaica, N. Y.
Leavitt, C. W.....New York City
Lee, E. H............Chicago, Ill.
Lee, E. M........Paterson, N. J.
Leighton, M. O., Washington, D. C.
Leister, S. H....Philadelphia, Pa.
Leland, O. M.......Ithaca, N. Y.
Lemen, W. C......New York City
Leon, H. M.......Brooklyn, N. Y.
Leonard, H. R...Philadelphia, Pa.
Lesley, R. W....Philadelphia, Pa.
Letson, T. H......New York City
Levine, L. M......New York City
Lex, W. I......Philadelphia, Pa.
Lindholm, C. B...Pittsfield, Mass.
Lindsey, A. R...Philadelphia, Pa.
Linton, H........Baldwin, N. Y.
Little, J. G..........Leonia, N. J.
Lobo, C..........New York City
Lockwood, W. D., Philadelphia, Pa.
Loewenstein, J...New York City
Logan, J........Mt. Holly, N. J.
Loughran, J. F...Kingston, N. Y.
Lowinson, O......New York City
Lucas, G. L.......New York City
Lucius, A........New York City
Luhrs, A. W...Jersey City, N. J.
Lundie, J........New York City
Lynde, C..........Walden, N. Y.

MacDonald, C., White Plains, N. Y.
MacGlashan, A..Jersey City, N. J.
MacGregor, R. A..New York City
Machen, H. B...Washington, D. C.
Macy, E. C......Hog Island, Pa.
Macy, F. H........Albany, N. Y.
McCarthy, D. F..Bronxville, N. Y.
McClintock, J. R..New York City
McConnell, I. W...New York City
McDanel, M. S., Wilmington, N. C.
McDowell, F. F..New York City
McGrew, A. B....Pittsburgh, Pa.
McIntyre, W. A., East Orange, N. J.
McLean, A......Brooklyn, N. Y.
McMillan, F. R..Philadelphia, Pa.
McMinn, T. J..Bridgeport, Conn.
McNab, W......Montreal, Canada

McNaughton, W. C., New York City
McNeal, J. . . . . Easton, Pa.
McPike, M. J. . . Brooklyn, N. Y.
Main, C. T. . . . . Boston, Mass.
Manley, H., Jr. . Elmhurst, N. Y.
Manley, L. B. . . Philadelphia, Pa.
Marston, A. . . . . Ames, Ia.
Martin, B. C. . . . . . Hudson, N. Y.
Martin, J. . . . . New York City
Mason, F. . . . . New York City
Matlaw, I. S. . . . . . New York City
Mattimore, H. S. . . Harrisburg, Pa.
Mead, C. A. . . . . Newark, N. J.
Mead, E. . . . . Berkeley, Cal.
Meadowcroft, W. . . New York City
Mebus, C. F. . . . Philadelphia, Pa.
Mehren, E. J. . . . . New York City
Meigs, J. . . . . Philadelphia, Pa.
Melick, N. A. . . . . . Newark, N. J.
Melius, L. L. . . . . . New York City
Menefee, F. N. . Ann Arbor, Mich.
Mercer, C. H. . . . . . Bethlehem, Pa.
Merriman, M. . . . . . New York City
Merriman, R. M. . . New York City
Merryman, W. C. . New York City
Metcalf, L. . . . . Boston, Mass.
Miller, A. B. . . . . Montclair, N. J.
Miller, M. M. . . . . . New York City
Miner, J. H. . . . . . New York City
Mitchell, S. P. . . . Philadelphia, Pa.
Modjeska, R. . . . . Chicago, Ill.
Moeller, H. L. . . . . Hoboken, N. J.
Mogensen, O. E. . . New York City
Molina, V. . . . . New York City
Moore, C. H. . . . . . New York City
Moore, E. J. . . . . . . Yonkers, N. Y.
Moore, F. C. . . . . . New York City
Moore, F. F. . . . . . New York City
Moore, W. H. . . New Haven, Conn.
Morse, C. F. . . Good Ground, N. Y.
Moss, R. E. . . Glen Ridge, N. J.
Moss, W. B. . Tompkinsville, N. Y.
Mowlds, E. . . . . . . Edge Moor, Del.
Moyer, A. . . . . New York City
Muirhead, J. H. H., New York City

Nelson, A. H. . Atlantic City, N. J.
Nelson, F. B. . . . . . New York City
Nelson, J. W. . . . . . New York City
Nelson, W. . . . . Laconia, N. H.
Newcombe, W. T. . . . . Easton, Pa.
Newell, H. E. . . . . New York City
Newkirk, S. F., Jr., Glen Ridge, N. J.
Nial, W. A. . . . . Troy, N. Y.
Nichols, C. H. . New Haven, Conn.
Nichols, W. S. . . Philadelphia, Pa.
Nixon, C. . . . . . Washington, D. C.
Noble, F. C. . . . . . . New York City
Norcross, P. H. . . . . . . Atlanta, Ga.
Norelius, L. M. . . Philadelphia, Pa.
Norris, W. H. . . . . . . Portland, Me.

O'Connor, J. A. . . . . Albany, N. Y.
Odell, F. S. . . . Port Chester, N. Y.
Ogden, H. N. . . . . Ithaca, N. Y.
Ogden, J. C. . . . . . New York City
Okubo, T. . . . . New York City
Okun, A. H. . . . . . Brooklyn, N. Y.
Orlian, I. . . . . Philadelphia, Pa.
O'Rourke, F. H. . Philadelphia, Pa.
O'Rourke, J. F. . . New York City
Orrok, G. A. . . Willimantic, Conn.
Osborn, I. S. . . . . Cleveland, O.
Ott, S. J. . . . . . Rutherford, N. J.
Owen, E. H. . . . Bridgeport, Conn.

Paaswell, G. . . . . . . New York City
Paddock, H. C. . . . . Caldwell, N. J.
Palmer, G. B. . . Philadelphia, Pa.
Pardee, J. T. . . . . Cleveland, O.
Parker, C. J. . . . . . New York City
Parker, W. P. . . . Philadelphia, Pa.
Parlin, R. W. . . . . . New York City
Parmley, W. C. . . . New York City
Parsons, H. de B. . . New York City
Patterson, C. A., Torrington, Conn.

Payrow, H. G......Bethlehem, Pa.
Peck, L. F.......Hartford, Conn.
Pegram, G. H.....New York City
Peiser, F.........Paterson, N. J.
Pellissier, G. E....Holyoke, Mass.
Pendergrass, R. A., Philadelphia, Pa.
Pendlebury, E...Arlington, N. J.
Perkins, A. H......Albany, N. Y.
Perkins, Alva H., St. Augustine, Fla.
Perkins, E. T........Chicago, Ill.
Perrine, G........New York City
Perry, F. W......Brooklyn, N. Y.
Perry, Lynn..........Easton, Pa.
Philips, J. H...Glen Ridge, N. J.
Phillips, A. E..Washington, D. C.
Phillips, A. L...Philadelphia, Pa.
Phillips, J. M.....Boonton, N. J.
Picken, M. W.....New York City
Pierce, C. A......Brooklyn, N. Y.
Pierce, C. H........Boston, Mass.
Pinner, G.........New York City
Pohl, C. A......New York City
Pollock, C. D.....Brooklyn, N. Y.
Poole, C. A......Rochester, N. Y.
Poore, H. C..East Braintree, Mass.
Porter, G. F..Walkerville, Canada
Porter, J. E......Yonkers, N. Y.
Porter, J. M.........Easton, Pa.
Potter, A.........New York City
Potts, C..........New York City
Powell, C. U......Flushing, N. Y.
Pratt, A. H........Newark, N. J.
Pratt, E. A......Philadelphia, Pa.
Prentis, E. A., Jr..New York City
Pratt, F. E..........Altoona, Pa.
Preston, H. W......Elmira, N. Y.
Price, P. L.....Hempstead, N. Y.
Priest, B. B.......New York City
Proctor, R. F......Baltimore, Md.
Purdy, C. T.......Monroe, N. Y.
Purver, G. M.....Brooklyn, N. Y.

Quimby, H. H...Philadelphia, Pa.
Quimby, J. H.....New York City
Quincy, C. F......New York City
Quincy, R. B......New York City

Ralston, J. C.....Spokane, Wash.
Randorf, C. A.....Buffalo, N. Y.
Rankin, E. S.....Newark, N. J.
Reeves, W. F......New York City
Reichmann, A.......Chicago, Ill.
Reid, H. A...........Warren, O.
Reimer, A. A...East Orange, N. J.
Reppert, C. M.....Pittsburgh, Pa.
Requardt, G. J....Baltimore, Md.
Reynolds, J. O.....New York City
Rhett, A. H.......New York City
Richmond, W. S., Philadelphia, Pa.
Ricketts, A. T....Wyoming, N. J.
Ridgway, R.......New York City
Rights, L. D.....New York City
Rindsfoos, C. S...New York City
Robbins, D. W.......Utica, N. Y.
Robbins, F. H.....New York City
Roberts, L. B...Washington, D. C.
Roberts, R. F......New York City
Roberts, W. W., Jr., Brooklyn, N. Y.
Robinson, E. F., Newport News, Va.
Robinson, E. W...New York City
Robinson, R. M....Hudson, N. Y.
Rodman, G. E.....New York City
Rogers, E. H..West Newton, Mass.
Rohrer, J. B.......Lancaster, Pa.
Rose, R. V...Niagara Falls, N. Y.
Ross, R. J.......Hartford, Conn.
Rourke, L. K......Roxbury, Mass
Rowland, W......New York City
Ruckes, J. J., Jr..New York City
Rugg, W. F...White Plains, N. Y.
Ryder, E. M. T...Yonkers, N. Y.

Sabin, A. H.......New York City
Sackett, A. J......Newark, N. J.
Sackett, R. L...State College, Pa.
Sacks, S. I......Philadelphia, Pa.
Sanborn, F. B......Boston, Mass.

Sanborn, J. F.....New York City
Sands, E. E.......New York City
Sargent, E. H......Albany, N. Y.
Sargent, P. D......Augusta, Me.
Sartz, J. P.......New York City
Saunders, R. S.,
College Point, N. Y.
Saville, C. M.....Hartford, Conn.
Sayers, E. L......New York City
Schall, F. E.......Bethlehem, Pa.
Scheidenhelm, F. W.,
New York City
Schermerhorn, R..New York City
Schmid, F. R......New York City
Schreiber, M......Newark, N. J.
Schusler, G. W....Pittsburgh, Pa.
Schwarze, C. T....New York City
Schweizer, R.,
Ridgefield Park, N. J.
Scott, W. V.....Flushing, N. Y.
Scrimshaw, J. F..Arlington, N. J.
Seabury, G. T...Providence, R. I.
Seaman, H. B.....New York City
Seaman, W. L...Glen Cove, N. Y.
Searle, C. D......New York City
Senior, F. S...Montgomery, N. Y.
Serber, D. C......New York City
Shaffer, I. O......Brooklyn, N. Y.
Shailer, R. A.......Boston, Mass.
Shaughnessy, C. S.,
New York City
Shaw, G. H.....Philadelphia, Pa.
Shenehon, F. C.,
Minneapolis, Minn.
Sherman, H. J...Camden, N. J.
Sherrerd, M. R...Newark, N. J.
Sherron, G. A...Philadelphia, Pa.
Shoemaker, L. H..Pittsburgh, Pa.
Shute, J. S......Philadelphia, Pa.
Sikes, Z. H........Yonkers, N. Y.
Silliman, C.....Washington, D. C.
Simpson, J. T......Newark, N. J.
Singstad, O......Brooklyn, N. Y.
Sitt, W. T........New York City
Skillin, E. S......New York City
Skinner, F. F...Mt. Vernon, N. Y.
Skinner, J. F....Rochester, N. Y.
Sloan, S. A......Philadelphia, Pa.
Sloan, W. G.......New York City
Smith, A...........Roselle, N. J.
Smith, B. L.......Baltimore, Md.
Smith, E. U.....Philadelphia, Pa.
Smith, J. R.......Bethlehem, Pa.
Smith, J. W......New York City
Smith, M. H......New York City
Smith, R. B......New York City
Smoley, C. K.......Scranton, Pa.
Smoyer, L. I...Woodhaven, N. Y.
Snell, T. C. B.....Newark, N. J.
Snow, J. B...Forest Hills, N. Y.
Snyder, F. A.......Summit, N. J.
Snyder, G. D......New York City
Soest, H. C.......New York City
Solomon, G. R...New York City
Soper, G. A.......New York City
Spear, W. E......Merrick, N. Y.
Spencer, H........New York City
Sperry, H. M.....New York City
Spivey, W. T....Philadelphia, Pa.
Sprague, N. S.....Pittsburgh, Pa.
Stark, C. W......Yonkers, N. Y.
Starr, H. H......Philadelphia, Pa.
Stearns, R. H......Boston, Mass.
Stehle, F. C.........Towanda, Pa.
Stein, J. B........Yonkers, N. Y.
Steinman, D. B...New York City
Stepath, C......Brooklyn, N. Y.
Stern, E. W......New York City
Stevens, C. H....Philadelphia, Pa.
Stevens, E. W...Jersey City, N. J.
Stevens, H. C.....New York City
Stevenson, W. F.,
New Rochelle, N. Y.
Stewart, S. J..Camp Upton, N. J.
Stieve, W. M...Washington, D. C.
Stiles, A. I.......New York City
Stoddard, R. F.....Milford, Conn.
Storey, F. W......New York City
Stowe, H. C.....Brooklyn, N. Y.
Stowitts, G. P....Yonkers, N. Y.

Strachan, J. . . . . . Brooklyn, N. Y.
Strehan, G. E. . . . . New York City
Strobel, C. L. . . . . Chicago, Ill.
Strong, J. B. . . . . . Hillburn, N. Y.
Stuart, F. L. . . . . . New York City
Stuart, J. T. . . . . Philadelphia, Pa.
Sturdevant, J. H., Poughkeepsie, N. Y.
Swaab, S. M. . . Philadelphia, Pa.
Swain, G. F. . . . . Boston, Mass.
Swezey, E. E., Clinton Corners, N. Y.
Swindells, J. S. . . Brooklyn, N. Y.

Taber, G. A. . . . . Brooklyn, N. Y.
Tait, H. . . Long Island City, N. Y.
Talbot, A. N. . . . . Urbana, Ill.
Talbot, E. . . . . . . Englewood, N. J.
Tallman, L. . . . . . Brooklyn, N. Y.
Taylor, C. F. . . . . . New York City
Taylor, E. A. . . . . Worcester, Mass.
Taylor, M. P. . . San Antonio, Tex.
Taylor, W. G. . . . . Newark, N. J.
Tenney, W. R. . . . . Brooklyn, N. Y.
Terry, A. H. . . . . Bridgeport, Conn.
Terry, J. H. . . . . . Philadelphia, Pa.
Thacher, E. . . . . . . New York City
Thackray, G. E. . . Johnstown, Pa.
Thayer, N. A. . . . . New York City
Thomas, C. D. . . Brooklyn, N. Y.
Thomes, E. H. . . . . Jamaica, N. Y.
Thompson, S. C. . . New York City
Thompson, S. E. . . Boston, Mass.
Thomson, T. K. . . . New York City
Thomson, W. B. . . . Cleveland, O.
Thorn, H. B. . . . . . . New York City
Thurlow, O. G. . Birmingham, Ala.
Tidd, A. W. . . White Plains, N. Y.
Tighe, J. L. . . . . Holyoke, Mass.
Tilden, C. J. . . New Haven, Conn.
Timberlake, S. M. . Brooklyn, N. Y.
Tompkins, E. De V., New York City
Tower, J. W. . . New York City
Trautwine, J. C., Jr., Philadelphia, Pa.
Travers-Ewell, A. . New York City
Tribus, L. L. . . . . . New York City
Triest, W. G. . . . . . New York City
Trimble, R. D. . . . . Richmond, Va.
Trout, C. E., West New Brighton, N. Y.
Trumbull, M. K. . . New York City
Tucker, L. W. . . . . New York City
Tull, R. W. . . . . . . New York City
Tuttle, A. S. . . . . . New York City

Ulrich, E. B. . . . . Reading, Pa.
Ungrich, M. J. . . . . New York City
Upham, C. M. . . . . Dover, Del.
Upton, J. . . . . Flushing, N. Y.
Urquhart, L. C. . . . . . Ithaca, N. Y.

Van Cleve, H. P. . . Cranford, N. J.
Van Dyke, C. W. . . New York City
Van Scoyoc, H. S., Montreal, Canada
Verrill, G. E. . . New Haven, Conn.
Villadsen, T. A. B., Salt Lake City, Utah
Vincent, J. I. . . . . . New York City
Vogdes, J. J. . . . . Philadelphia, Pa.
Vogel, J. L. . . . . . . Chatham, N. J.
Voynow, C. B. . . Philadelphia, Pa.
Vredenburgh, W. . . New York City

Waddell, J. A. L. . New York City
Wadsworth, J. E. . New York City
Wagner, E. L. . . . . New York City
Wagner, S. T. . . Philadelphia, Pa.
Wait, B. H. . . . . . . New York City
Waite, D. C. . . . . Brooklyn, N. Y.
Waite, G. B. . . . . . . New York City
Walker, J. J. . . Dobbs Ferry, N. Y.
Walker, J. W. . . Philadelphia, Pa.
Wall, E. E. . . . . St. Louis, Mo.
Waltman, W. D. . . . . Denver, Colo.
Warnock, W. H. Cedarhurst, N. Y.
Warwick, C. L. . . Philadelphia, Pa.
Watson, G. L. . . . . . . Newark, N. J.
Watson, W. J. . . . . . Cleveland, O.
Watt, D. A. . . . . . . Hoboken, N. J.

Webster, G. S. . Philadelphia, Pa.
Weed, I. . . . . Brooklyn, N. Y.
Weed, L. W. . . . . . . New York City
Wegmann, E. . . . . . Yonkers, N. Y.
Weidman, J. H. . . Syracuse, N. Y.
Wells, C. E. . . White Plains, N. Y.
Wells, E. . . . . Georgetown, Ky.
Welty, H. T. . . . . . New York City
Wendell, E. W., Hudson Falls, N. Y.
Wendt, E. F. . . . Washington, D. C.
Wetzler, W. H. . . New York City
Weymouth, A. . . . Flushing, N. Y.
Weymouth, F. E. . . Denver, Colo.
Wheeler, R. C. . . . . New York City
Whinery, S. . . . . . . New York City
Whitcraft, L. N., Hackensack, N. J.
White, B. E. . . . . Utica, N. Y.
White, L. . . . . New York City
White, W. M. . . . . Fanwood, N. J.
Whitman, E. B. . . Baltimore, Md.
Whitney, G. C. . . Brooklyn, N. Y.
Whitson, A. H. . . . Flushing, N. Y.
Whitson, M. J. . Washington, D. C.
Whittier, T. T. . Brooklyn, N. Y.
Widdicombe, S. H., New York City
Wigley, C. G. . . . . . New York City
Wilbanks, J. R. . . . . Columbus, O.
Wilcock, F. . . . . New York City
Wilkerson, T. J. . Beaver Falls, Pa.
Williams, C. G. . . Plainfield, N. J.
Williams, F. . . . East Orange, N. J.
Williams, F. P. . . . . Albany, N. Y.
Williams, G. S. . Ann Arbor, Mich.
Williams, J. P. J. . New York City
Williams, T. S. . . . New York City
Willoughby, J. E., Wilmington, N. C.
Wilmot, J. . . . . New York City
Wilmot, S. . . . . . Providence, R. I.
Wilson, H. K. . . East Orange, N. J.
Wilson, W. T. . . . . . New York City
Winsor, F. E. . . Providence, R. I.
Winsor, G. A., Pleasantville, N. Y.
Winsor, H. D., West New Brighton, N. Y.
Witmer, F. P. . . East Orange, N. J.
Wolfel, P. L. . . . . Pittsburgh, Pa.
Wolff, A. D., Jr. . Hudson, N. Y.
Wolff, R. . . . . Glendale, N. Y.
Wolpert, O. . . . . . . New York City
Woodard, S. H. . . . New York City
Woodcock, H. W. . Brooklyn, N. Y.
Woodruff, G. B. . . . Bethlehem, Pa.
Woodworth, R. B. . Pittsburgh, Pa.
Wyckoff, C. R. . . . . New York City
Wyman, A. M. . . Philadelphia, Pa.

Yates, C. C. . . . . New York City
Yates, J. J. . . . . New York City
Yates, W. H. . . . . . . New York City
Yereance, A. W., South Orange, N. J.
Yereance, W. B. . . New York City
Young, H. A. . . . . New York City

Zook, M. A. . . . Washington, D. C.

REPORT OF THE COMMITTEE OF THE BOARD OF DIRECTION APPOINTED TO STUDY THE REPORT OF THE COMMITTEE ON DEVELOPMENT

PRESENTED TO THE BOARD ON JANUARY 19TH, 1920

SYNOPSIS

The Report commends the work of the Committee on Development and generally divides its work into:

I. Fundamental changes in creating a new organization for co-operative work with other affiliated Societies.

II. Recommendations for internal betterment of the American Society of Civil Engineers.

The Report further outlines fundamental ideas which it is believed actuated the Committee in its work, including emphasis desired by certain members and also adds one motive which this Committee believes many members of the Society desire, which is not expressed in the Committee's report on Development.

The Report states the four issues raised by the Committee on Development which are believed to be most vital, as follows:

I. Shall the American Society of Civil Engineers use its power and influence to bring together for welfare purposes the Engineering and related technical professions of America?

II. If so, shall it assent to the formation of a new and somewhat unrestricted organization as proposed by the Development Committee?

III. Or shall it develop and broaden the basis of the present Engineering Council as well as make it more representative than at present, all as proposed herein?

IV. Shall the dues of Non-Resident Corporate Members be raised not less than $5.00 nor more than $10.00 per annum for these purposes?

Following this, the salient features of the Report are:

Part I. Fundamental changes and new organizations.

Vital proposition is Engineering unity.

National Societies not well co-ordinated in new organization.

Representation discussed and criticized.

New organization possibly controlled by semi-technical affiliations. Example.

Criticism summarized in six objections.

New plan outlined for strengthening Engineering Council.

Part II. Internal betterment.
Committee's suggestions generally commended.
The programme suggested, as understood by us, to be gradually and not immediately accomplished.
Certain suggestions of the Committee are discussed, as follows:
1st.—Local Sections and additional meetings.
Society experience and practice.
2d. —Programme for better co-ordination of technical literature.
3rd.—Control of Committeemen and Directors and their attention to their duties.
4th.—Reference of membership applications to Local Sections.
5th.—Membership requirements not discussed.
Suggest it be postponed until external relations are settled.
6th.—The Budget Committee's report analyzed.
Table of prospective expense.
Larger dues than suggested by Budget Committee thought necessary and recommended.
7th.—Conclusion: The two ideas of society welfare shown not to be incompatible.
Great care recommended in making changes.
8th.—Recommendations for full discussion and the submission of four questions to the membership of the Society.
Appendix A.—Outline of plan to broaden present Engineering Council and make it more representative.
Appendix B.—Classification of suggestions of the Committee on Development for internal improvement.

To the Board of Direction of the
American Society of Civil Engineers.

Gentlemen:

Your Special Committee of the Board of Direction, appointed October 14th, 1919, to study the report of the Committee on Development and review its suggestions for the benefit of the Board of Direction, would respectfully report its conclusions herewith.

The report of the Committee on Development of the American Society of Civil Engineers, presented to the Board October 14th, 1919, is one of the most spirited, human, and interesting documents which the Board has received for some years, giving internal evidence that the large and representative Committee has carefully studied the problem before it, and has given it the benefit of much profitable discussion. Your Committee of the Board feels that the Society is greatly indebted to the Committee on Development and to its Sub-Committees for their devoted efforts to meet the duties the Board has imposed upon them.

In general, its recommendations resolve themselves into two classes:

1st.—Fundamental changes in our Constitution to further the creation of a new organization for co-operative work with other Affiliated Societies and for professional and public welfare.

2d.—Recommendations for internal betterment of the American Society of Civil Engineers and its technical activity, with suggestions for improvements, not all of which require radical changes in our present Constitution.

We are impelled to pass somewhat lightly over the second class of recommendations, not because they are unimportant, but because it seems to us more important at this time to discuss the few most vital recommendations rather than the numerous minor administrative changes.

Reading between the lines of the report, we think we note certain fundamental desires and aims, not always fully expressed, but quite distinctly to be inferred. If we are not mistaken, these are largely the reflection of the desires and aims of a large portion of the membership of the Societies as well, and it suits our purpose to outline them herein more carefully, as follows:

1st.—The engineers of this country are earnestly desirous of greater unity and solidarity. We all wish to make our profession more efficient not only for the benefit of the profession itself, but, as well, for the benefit of the public, and there exists a general desire to develop the usefulness and effectiveness of the profession in its public aspect and relations.

2d.—The profession has grown so rapidly in the last generation that the older forms of association have unquestionably become somewhat defective, in that they do not sufficiently permit and encourage local activity, cultivate the broader professional relations, increase our larger influence on local public affairs, and create closer connection between the outlying local sections and the governing boards. As now organized, the broader public welfare of the profession heavily overtaxes the time and attention of a relatively few of the older and more responsive members, the higher officers, and the governing boards, including members of Engineering Council, while there is not enough opportunity for Society work for the rank and file, especially in outlying communities, to keep them active and interested and enable them to register their wishes and influence.

3d.—There is everywhere a marked and well-defined impression that the Engineering Profession should have a larger influence for good in public affairs and that it should stand as a sound guide in the larger technical, economic, and engineering problems of the State and Nation. The importance of engineering in the late War and its suddenly enhanced value in the eyes of the public make this a psychological time to create professional unity of purpose and achievement.

4th.—Unquestionably the great body of engineers belonging to the several National organizations, while desiring professional co-operation of the closest kind, do not wish, and would undoubtedly reject any proposition which would tend to lower the standards of admission to their several memberships or destroy what has been slowly and carefully created in the way of efficient organization now in operation. A very considerable number of the profession will include the work of Engineering Council in this feeling.

The first, second, and third of the above propositions appear to be common to the thought of all of the Committee on Development, while the fourth proposition is apparently a feature which some members of the Committee appear to have wished to emphasize. If we have not misinterpreted the fundamental thought of the Committee, we are in accord with its spirit as above expressed, including the final proposition as well. But we would also like to add one more proposition which we do not find so clearly indicated in the Committee's report, although we believe it really lies in the hearts and minds of at least a considerable portion of the members of the Committee, as well as a large portion, if not a majority, of the members of the Society at large. This may be formulated as follows:

5th.—*In any co-ordination of the Engineering Profession in this country in which the technical activities of the State or Nation are to be discussed, or engineering matters of public welfare need guidance or advice and wherever professional ethics, status, standing, or compensation are under consideration generally, the American Society of Civil Engineers ought to have a reasonably proportionate, if not a leading influence in the deliberations, due to its long and honorable career, the distinguished character of its personnel, and its accumulated experience in technical and professional matters in this country and abroad.*

Your Committee cannot certainly know the mind of the Society at this stage of the discussion, but it believes that it is necessary to have the principal salient issues before it narrowed down and made as clear and simple as possible so that time will not be wasted in unintelligent discussion.

Our study of the report of the Committee on Development, and the included Joint Conference Committee's report, leads us to believe that the following issues are the first and most important matters to settle of all those presented by the Development Committee:

1st.—*Shall the American Society of Civil Engineers use its power and influence to bring together for welfare purposes the Engineering and related technical professions of America?*

2nd.—*If so, shall it assent to the formation of a new and somewhat unrestricted organization as proposed by the Joint Conference Committee's report?*

3rd.—*Or, shall it develop and broaden the basis of the present Engineering Council, as well as make it more representative than at present, all as newly proposed herein?*

4th.—*Shall the dues of Non-Resident Corporate Members be raised not less than $5.00 nor more than $10.00 per annum for these purposes?*

Having thus outlined our viewpoint, we will next take up as Part I the proposal to create a new National Engineering organization for public and professional welfare purposes.

PART I.

The Joint Conference Committee's Report.
(Section C).

The original resolution of the Board of Direction, adopted June 18th, 1918, creating the Committee on Development, provides that it was to report on the "purposes, field of work, scope of activity and usefulness, organization and methods of work of the American Society of Civil Engineers" and to make recommendation concerning these matters.

The suggestion of the formation of an entirely new "National Engineering Organization" to promote these objects really constitutes the most vital and fundamental part of the report of the Committee on Development, and, as such, requires a great deal of thoughtful study on the part of the membership of our Society as well as of the other National Societies before its ultimate effect and operation can be fully understood and appreciated.

The Joint Conference Committee has evidently in mind the desirability of preserving the good in the Societies that has so far been carefully built up, except perhaps in the case of the present Engineering Council, but apparently in its desire not to interfere with the work and organization of the present National Engineering Societies it seems to us to have gone to another extreme by proposing the creation of a new and separate organization, made up of a different rank and file, and so distinct and apart in its upper and governing structure from our present organization that the American Society of Civil Engineers, as a body, appears to have little part or influence in it.

That part of the Committee's report which deals with representation in the new National Council is not entirely clear.

We quote as follows:

"Each local, state, or regional affiliation or organization whose membership is not otherwise represented than through the National engineering or technical societies, shall be entitled to one representative in the National Council for a membership of from 100 to 1 000,

inclusive, and one additional representative for every additional 1 000 members, or major fraction thereof."

"Each National engineering or technical society shall be entitled to one representative for a membership of from 200 to 2 000, inclusive, and an additional representative for every additional 2 000 members, or major fraction thereof."

If we read this aright, members of the American Society of Civil Engineers belonging to Local Sections can only vote (separately) for their own National Society delegates to the new organization at half the rate of representation accorded other members of the Local Sections.

Mr. Frederick C. Noble, a member of the Committee on Development, has estimated that representation under this plan would be as follows:

No.	Kind	Members.	Council	Executive Board.
1	Am. Soc. C. E.	9 030	5	2
3	Other Founder Societies.....	28 002	14	7
27	Other National Societies....	31 913	30	8
12	Regional Societies..........	8 073	13	2
24	State Societies..............	10 226	25	2
50	Local Societies.............	20 567	40	5
		107 811	127	26

Mr. Noble says this takes the most favorable interpretation of the Committee's language, insofar as our membership is concerned, both of the paragraphs before quoted and of the outline for selection of the Executive Committee.

It is to be expected that the American Society of Civil Engineers must make some sacrifices if it elects to aid in unifying the profession, and it must expect in any larger organization to accept its proportional representation, but it is not apparent to us why it and the other National Societies should so largely cease to function directly in the councils of the new National Organization or be limited somewhat below proportionate representation as above disclosed.

A society expresses itself through its organization and acts through its appointed leaders, and as an organization the American Society of Civil Engineers and its official leaders appear to us, as we interpret the report, to have, as a body, no material influence in the new proposed National Association. We wonder if the Committee on Development fully appreciated the far-reaching effect of this proposal.

The report of the Committee on Development as regards the outlying Local Sections provides quite distinctly that each geographical district of the American Society of Civil Engineers shall elect its Directors by the *"direct vote of its corporate members"*, but the Joint Conference Committee's Report does not define the qualifications of those who are to be admitted to membership in the proposed local affiliations, and who

consequently have the power to determine the character of the national organization. It is also apparent that the Committee does not expect to confine strictly to the Engineering Profession the control of this new organization, but is looking principally to the impression to be made upon the public mind of large and widespread numerical strength of membership.

Doubtless there is much to be said for this point of view, but in becoming strong numerically it is quite possible to become weak in character and quality.

As the Joint Conference Committee's report now reads, it might be possible that a Local Association of Plumbers, styling themselves "Sanitary Engineers"—to all intents and purposes being technical men, in theory at least—could be admitted to the Local Sections, and by concerted effort elect a delegate from their own number to the National Council who might even become President thereof, and who would have more to say authoritatively about National technical problems of the country than the President and Board of Direction of the American Society of Civil Engineers.

There further appears to be no bar to such local technical associations as are in part more or less commercial in their aims, but which may be very liberal or even loose in admitting to their membership men who are not wholly desirable from an Engineering standpoint. If there is any one thing which we believe the Engineering Profession should most zealously guard, it is the standing of its membership and the character of its admission requirements. We feel, therefore, that thoughtful objection must be raised to this feature of the report of the Joint Conference Committee. There are also other objections, which are included in the following concise outline:

1st.—The Joint Conference Committee's report does not sufficiently confine the voting power of the proposed new National Organization to the corporate members of the present National Engineering Societies, and of such other allied technical societies as are clearly predominately professional in their aim, *and who are equally careful with the present National Societies in the admission to their membership.*

2d.—The proposed new organization does not have close enough connection and co-ordination with the officers and Boards of Direction of the present National Societies and such other National and Regional Societies as it may see fit to admit to its membership.

3d.—The Committee's plan creates a large amount of new, somewhat complicated, and expensive machinery that appears to us to be unnecessary, and which it may be reasonable to doubt can be made to work smoothly for some time to come, at least insofar as the present experience of Engineering Societies has gone.

4th.—The plan for the new organization is so drawn as largely to deprive the present National Societies of any considerable influence in large public or National technical problems in which they are

naturally interested and in which they are preeminently capable of having voice.

5th.—The plan commits the welfare of the Engineering Profession to a new and untried organization without history, precedent, or experience, from which semi-professional, and even semi-commercial Local Societies are apparently not only not barred, but possibly may become from time to time a predominating influence.

6th.—The representation in the new organization accorded to the four National Societies is numerically insufficient in view of their numbers, experience, and standing.

In view of these objections and others of a more minor character which have suggested themselves to us after a study of the Committee's plan, it has finally seemed wise to us to suggest an alternative plan which we believe is more direct and simple in its method and more conditioned on outgrowth of what we now have in existing organization. This plan may be styled a *plan to broaden and develop the powers of the existing Engineering Council as well as to place it on a more representative basis than at present.*

The present Engineering Council is an organization of the National Engineering Societies of the United States, consisting of a total of 25 representatives from the Founder Societies and the American Society for Testing Materials. Its formation, purpose, and the scope of its work are explained on pages 43 and 44 of the Society Year Book for 1919. It has been in active operation for two and one half years, and is now conducting a well planned program of professional welfare work.

But the present Engineering Council suffers from three difficulties:

1st.—It derives its authority from the Boards of Direction of these Societies, which may not always agree as to its policies and actions.

2d. —Its work does not have sufficient publicity among the Engineering rank and file which is supporting it.

3d. —Its members are not directly elected by, nor does Council report directly to, the membership of over 40 000, which it theoretically represents.

To remedy these defects, it is suggested that the officers and Boards of Direction of the present National and their Affiliated Engineering Societies could form, *ex-officio,* a National Engineering Council for the purposes of professional unity, which would, in effect, continue the work of the present Engineering Council, and that to the Council thus formed might be added, if desired, delegates from State or Local Councils to be formed throughout the country.

Some such arrangement as this would greatly simplify the Committee's plan by doing away with the necessity for any additional

organization, with all its elective machinery, and while continuing the present Engineering Council, would make it more representative without dislodging our present Societies from their natural line of influence, or halting our joint activities.

In such a simplified plan, the National Engineering Council thus created should probably meet but once in two years as a general National Conference, and should at that time outline a national professional platform and choose its Chairman, Officers, and Executive Committee, much as suggested in the Joint Conference Committee's report. Such Executive Committee would in effect be the real working body and should conduct without break the national and general work now so well started by the present Engineering Council.

In order to crystallize this solution of the problem, as an alternative plan to the one suggested in the Joint Conference Committee's report, we submit herewith as Appendix A, an outline scheme for such Joint Engineering Council, and recommend its consideration and discussion in connection with the whole subject.

PART II.

The Development Committee's Recommendations for Internal Betterment.

Turning now to the Committee's recommendations for internal betterment of the American Society of Civil Engineers, it is to be noted that a number of those made for the internal activities of the Society have already been, or are now being introduced either by Joint Committees of the Founder Societies or by the Engineering Council and its general Committees. The Committee on Development, however, recommends some new and interesting forms of activity. Some of these would require changes in the Constitution and some would not. All of the Committee's recommendations for internal improvement we have classified as shown in Appendix B.

We do not think it was in the mind of the Committee on Development that the profession could at once take over all its suggested activities. Obviously, the programme is rather one to grow towards, and as such is commendable. Obviously too, some of the activities may be by tentative trial found unworkable, and others not now foreseen might be added, but, considering it as a move toward the greater usefulness of our Society to the Engineering Profession, we are heartily in sympathy with the program generally.

We can but touch lightly on some of the suggestions. This feature of our report must, therefore be considered only as random observations, and not a complete review of this part of the Committee's report.

Some of the more important recommendations are the following:

1ST.—LOCAL SECTIONS AND ADDITIONAL MEETINGS.

Concerning the radical change in the subdivision of the country whereby Local Associations are hereafter to be called "Local Sections", it is proposed that each geographical district of the Society should be sub-divided, with clearly defined boundaries, and that every member be assigned to his local section so that his activities may center largely in his locality. This recommendation seems to have great merit and should be carefully considered, but some of the machinery suggested to meet this revision and provide for a new organization as well, seems to be cumbersome and much of it will certainly be more expensive for the membership than is indicated in the reported budget. A large number of conferences and meetings are called for which members are expected to attend, in some cases paying their own traveling expenses, and in others receiving mileage. It is evident that a new burden is laid upon the time and attention of the profession as a whole if all of the District Conventions, Annual Conventions, and Conferences, as well as the four Annual and other Co-operative and Committee meetings proposed, are carried out.

Those who know most about Engineering Society management find that there are many members who are quite content to pay their $15.00 per year to have their names in the Society's catalogue and to wear the Society's pin, and who never really seem to want much more than that from the Society. There are also quite a number who would resent being asked to put personal time, expense, and energy into Society and Committee work, and who believe they should get more out of the Society than they put in. These two classes undoubtedly need the education of more Society activity in their immediate neighborhood, and, fortunately, there are in every community many engineers who enjoy such work and desire enlarged opportunity for this kind of active service.

Engineers are generally busy men, and when we recall the small proportion in attendance at our present meetings, with the great difficulty of securing attendance at Committee meetings, even where mileage is paid, we can but gravely doubt whether all these new forms of activity proposed by the Committee will be supported by the patriotism and pocketbook of the Society membership. Any revolutionary changes of this kind which did not at once meet with general support would be expensive and disastrous.

On the other hand, if they do succeed, and are supported, they will undoubtedly greatly increase our unity in the profession by frequent conference and better understanding of each other's aims. There is certainly some force to the criticism that our social conventions are not as well attended as are technical meetings both in our Society and other

Societies and a change in the character of such meetings might promote more interest in them.

2D.—PROGRAMME OF PAPERS.

Some of the suggestions made by the Committee appear to us to be theoretically most excellent, but practically not entirely easy of accomplishment, as, for instance, the scheme for securing a properly rounded programme of papers which will show the general progress of technical thought, all laid out by the Publication Committee and facilitated by a standing Committee on each subject. This is undoubtedly an ideal procedure, and if it could be fully realized would be a wonderful advance over present conditions. Experience shows, however, that it is quite difficult to force papers from engineers on chosen subjects unless they have some personal and even practical reason for contributing them to the Society's publications. A generous but enlightened self-interest is usually the main motive which produces valuable technical literature. It is probable, however, that something can be done to improve the Society's technical literature, and that a well planned programme may encourage the production of valuable papers that would not otherwise appear.

3D.—STATUS OF COMMITTEES AND DIRECTORS.

Some of the suggestions of the Committee would be quite effective if members of the Society having duties to perform were receiving compensation for their time, but it must not be overlooked that such members are almost always *giving* their valuable attention to Society affairs, and should on that account receive more than usual consideration.

Thus, the suggestion that Committee members be dropped for non-attendance or inactivity (A. 3), that the Publication Committee have direct charge of the Editorial Staff (A. 5) (a very arduous task), and that Directors be required to visit the Local Associations once each year, usually at their own expense (B. 1 l.) are all more or less desirable, but all in our opinion cannot properly be rigidly enforced. In the first case, for instance, we believe more can be accomplished by exercising greater care in the selection of Committee members and urging them to their best efforts than by removing them for neglect of duty.

In the matter of publication, we are somewhat afraid of a constantly changing Publication Committee in direct charge of the Editorial Staff.

The requirement for frequent travel and visits might be a positive deterrent to men otherwise best qualified for Directors, and it is suggested that it would be better to ask that a Director keep himself in close touch with the Local Associations of his district to the greatest practicable degree.

4TH.—MEMBERSHIP APPLICATIONS REFERRED TO LOCAL SECTIONS.

It is a sound idea to recommend, as is done in Sec. 1 (*i*) that application for membership in the Society should be referred to the Local Associations for consideration. We do not understand, however, that the Local Association should have power to do anything more than make recommendations. In other words, their position should be much the same as, but perhaps of more importance, than one of the members to whom, under the present Constitution, it is necessary for applicants to refer.

5TH.—MEMBERSHIP QUALIFICATIONS.

In the matter of membership qualifications, there is much to be said, and there will be many men of many minds.

In a general way, we agree that full membership qualifications should be held up to a high grade, and that other recommendations of the Committee have great merit. But, for the present, we suggest that changes in membership (and other internal matters) should be postponed and the attention of the Society focused upon its external relations until that fundamental part of the program is disposed of, otherwise great confusion will result.

6TH.—THE BUDGET.

The Budget Committee reports under date of November 11th that $25 212.00 would be the total additional expense of all activities called for by the Committee plan. We note, however, that it evidently considers this amount a minimum. It calls attention to the fact that it does not cover greatly increased Society work above the matters specifically recommended by the Committee on Development. It says (page 28):

"The element of contingent expense, plus or minus has not been dealt with in the summation of estimated additional cost, as it is obvious that the total will be affected by the extent in which the present activities will be increased."

It also calls attention to the probability that the Society's surplus will be seriously reduced, and the Society's expenses will be increased by reason of the lessened purchasing value of the dollar.

The original report does not deal with the present resident membership dues which are now in force in New York City and vicinity. But we infer (as does the Budget Committee) that, as the semi-monthly meetings at the Society house are to be abolished, the New York District membership is expected to organize Local Sections, probably a number of them, and that the excess of resident over non-resident dues will, as a matter of consequence, be abolished. These excess dues now bring into the Society a revenue of from $15 000 to $16 000 per year, which, if abolished, must be added to the minimum cost estimated

by the Budget Committee, and will thus raise its total estimate to at least $40 000, in order to carry out the recommendations of the Committee on Development both as to internal development of our Society and external co-operative relations, all of which must be derived from the general membership. This addition we compute will raise present Member and Associate Member dues from $15.00 per annum to about $20.00 per annum, and Associate and Junior dues from $10.00 per annum to $12.00 per annum, although the latter increased amount from Juniors is not strictly necessary.

The present budget of the Engineering Council is about $50 000 per annum. Its members advise us that this amount is not sufficient for the many needs at present pressing upon the attention of the Council.

The Budget Committee hopes that $80 000 will be available to the new National Council under the Committee plan.

Inasmuch as this whole movement is largely directed to obtaining greater public and professional activity, we believe that $100 000 is not too much for the new National Engineering Council to begin with. The present Council is doing a large amount of useful work with its limited budget, and it now suffers principally from lack of publicity among its supporting membership, who have little knowledge of its activities and progress. It needs a publicity organ and more financial support.

To do all this well and further to support regional and local welfare work, which will undoubtedly be later called for, as well as properly to provide for such activities and contingencies as are not yet outlined, and create a reasonable surplus, will require a Society income very much larger than at present. We believe that if the dues are raised fully and properly to carry out the Committee plan, the dues of non-resident members must be increased to an equality with those now required from resident members; that is, from the present $15.00 per annum for Non-resident Corporate Members, to $25.00 per annum for all Corporate Members and for Juniors and Associates from $10.00 per annum to $15.00 per annum, although the dues for Juniors could be kept at $12.00 per annum, or even as they are at present if it is thought desirable.

The following table will illustrate the proposed increased cost of the new activities to the members, Budget A being the present approximate income from membership, Budget B the minimum amount to be raised in accordance with the Budget Committee's report, and Budget C the amount which we think will ultimately have to be raised for the Committee plan and the new organization which will carry out any unified public and professional welfare movement what is really broad and effective.

TABLE SHOWING APPROXIMATE PRESENT AND PROPOSED BUDGETS.
(Membership Revenue only.)

Approximate Membership Jan. 1, 1918.	Present Non-Resident Dues.	A. Present Approximate Revenue.		B. Budget Committee's Report Minimum Needs.		C. Our Estimate, Maximum Needs.
3 800 Members...	@ $15. =	$57 000	@ $20. =	$76 000	@ $25. =	$95 000
4 420 Assoc. Mem.	@ $15. =	66 300	@ $20. =	88 400	@ $25. =	110 500
160 Associates..	@ $10. =	1 600	@ $12. =	1 920	@ $15. =	2 400
580 Juniors...	@ $10. =	5 800	@ $12. =	6 960	@ $15. =	8 700
		$130 700		$173 280		$216 600
N. Y. Resident Members, Extra..............		15 500		......		......
Entrance Fees (1918)...		15 000		15 000		15 000
Total Revenue from Membership........		$161 200		$188 280		$231 600
Additional over present Revenue..........				27 080		70 400
Additional on Membership at large, after abolishing Resident Membership				42 580		85 900

It is the opinion of your Committee, therefore, from a study of the above financial statement that if the American Society of Civil Engineers seriously intends to join in the movement to unify and expand the activities of the Profession of Engineering in this country they must confront a radical raise in dues, for if we are going to do it at all we must do it well.

7TH.—CONCLUSION.

Finally, it is our unanimous opinion that in matters of amalgamation with other National Societies and related organizations we should proceed with great caution.

One of our Committee writes:

"When I consider these welfare movements and the politics involved my mind goes back to the reason why, at the time of my application, I desired to become a member of the American Society of Civil Engineers, and why the young engineers of the country now wish to become members."

"I believe it is not from any idea of participating in civic affairs, or in raising the scale of wages, but rather that the American Society of Civil Engineers, essentially an Academic Society, may be viewed in the light of an institution of learning. Its certificate of membership is akin to a diploma from such an institution. Membership carries with it the eclat of being one of an exclusive and high grade organization, and insures a standing in the profession which all engineers are desirous of attaining. I believe we should continue to be exclusive and should maintain our high standards of membership."

Your Committee believes that this is an excellent point of view which should be fostered and encouraged in every way possible. At

the same time we believe the point of view expressed in the first part of our report on the greater growth and unity of the profession are also of vital importance and must be speedily given form. We believe both points of view can be preserved, harmonized, and welded together for joint professional advancement without sacrifice to either. To achieve this desirable step in advance, the Societies and the profession must be prepared to make more effort in personal time and in expenditure, but we do not believe it necessary to sacrifice any proper Society prestige. We believe the time has come when the great majority of the members of our Society are prepared to do all this, but only after the details have been worked out with such painstaking care that no mistakes will result, no ill considered steps will be rashly taken, and that the accumulated Society experience of the past will have been fully respected and utilized.

8th.—Recommendations.

1st. Your Committee recommends that opportunity for full and free discussion should be had by the Society at its coming Annual Meeting, and that all thoughtful criticism should be thereafter so published as to reach every member of the Society.

2d. That when in the judgment of the Board of Direction the problem is fully understood by the Society, the following propositions be put to a referendum vote for the information of the Board of Direction.

1st. Shall the American Society of Civil Engineers use its power and influence to bring together for welfare purposes the Engineering and related technical professions of America?

2d. If so, shall it assent to the formation of a new and somewhat unrestricted organization as proposed by the Joint Conference Committee Report?

3d. Or shall it develop and broaden the basis of the present Engineering Council, as well as make it more representative than at present, as proposed by the Committee of the Board of Direction?

4th. Shall the dues of Non-Resident Corporate Members of the American Society of Civil Engineers be raised not less than \$5.00 nor more than \$10.00 per annum for those purposes?

All of which is respectfully submitted,

John W. Alvord
Charles D. Marx
Herbert S. Crocker
Samuel T. Wagner*
John A. O'Connor
Committee.

**Mr. Wagner, in signing the Report makes the following statement:*

"While agreeing generally with most of the report, which I have signed with reservations, I regret that I cannot agree with the other

members of the Committee on certain features. On account of the shortness of the time and the fact that the members of the Committee are geographically so far apart, I have decided that it would be best to proceed in this manner so that the Board can give them such consideration they may merit.

"*Section 6.—The Budget.* Until it is definitely known what increased activities are to be taken up by the Society, there does not seem at this time to be proper justification for this part of the report. It is difficult to figure on the cost of any expenditures until it is known for what activities the money is to be spent, and it is believed that this was one of the reasons why the Budget Committee made no recommendations in their report as to the amount of the increase of dues. The discussion in our report as a whole is largely confined to that part of the Report of the Committee on Development designated as 'C—Relations with other National Societies and Related Organizations' which I feel is a mistake. This being the case, the figures given in the Table are apt to be misunderstood, as they include the cost of 'A—Society Activities', as well as the 'Joint Activities with other Societies', and thus if not read carefully convey the idea that the whole increased cost is for 'welfare' work.

"For the above reasons I think that it is inadvisable at this time to recommend the submission of Question No. 4 under recommendations as given in our report.

"*Section 8.—Recommendations.* I believe that our report should include questions in reference to 'Technical Activities' and 'Internal Relations' for a referendum vote of the membership. Many of the matters recommended by the Committee on Development are fundamental, important and cannot be ignored at this time. They are entirely separate and distinct from the 'external activities' which it is proposed we have with other Societies and cannot be confused with them. They can have no possible reference to any welfare work for the profession at large, and unless we are to treat them as of no importance in the development of the Society they should be included, with the questions which we recommend, and be placed before the Society to obtain their views. For this reason I feel that questions covering the fundamentals of the recommendations made by the Committee on Development under 'Technical Activities' and 'Internal Relations' should be included at this time.

"*In General.*—I fear that the general tone of our report will confuse the fact that the Committee on Development does not intend to create a 'new National Engineering Organization' in which the American Society of Civil Engineers is to be *absorbed and amalgamated,* but that its proposal is that we *'affiliate'* with a movement for the general welfare of the engineering profession, and that the prestige, standing and everything that the American Society of Civil Engineers stands for is to remain unchanged, except for such internal improvements as may be agreed upon by the membership.

"In joining in any such welfare movement, outside of the Society, for the benefit of the profession at large, and on a democratic basis, we cannot hope to exert any undue influence other than our just proportion. We have in Engineering Council at present, just such proportionate but not democratic representation and believe that we can

through the character of our representatives on any such affiliation, exert the influence that our experience and standing in the profession will demand. It will be noted that all applications for affiliation in the National Council as proposed by the Joint Conference Committee are to be passed upon by the National Council (see the following in the printed Report of the Committee on Development: Constitution, page 13; Purpose, page 14; Admission to National Council, page 15) which should be a sufficient safeguard.

"The Committee on Development (see page 11) indicated a moulding of Engineering Council into such a proposed National Organization 'by making it more democratic and founding it on direct representation of all engineers'. The proposed organization by our Committee (Appendix A.) is well outlined, the only doubt being whether it is democratic enough to fully answer the purpose. There can be no doubt that the work performed so far by Engineering Council is most praiseworthy when the restrictions and lack of funds under which it has been laboring in the past are considered.

SAMUEL T. WAGNER."

APPENDIX A

A Plan for Strengthening the Present Engineering Council and Extending the Scope of Its Influence

This plan contemplates a National Engineering Council, State Engineering Councils, and Local Engineering Councils with respective powers and membership, as follows:

1. National Engineering Council:

(*a*) Membership to consist of the officers and boards of direction of the four Founder Societies, the American Society for Testing Materials, and such other National technical societies as may later be chosen, two members from each State Engineering Council, and one member from each Local Council that may be formed.

(*b*) Powers and duties to consist of: Representing engineers in national affairs, insuring their public recognition, co-ordinating the activities of State and Local Engineering Councils, initiating action by engineering organizations generally that will result in benefit to the profession as a whole, and giving due publicity to its own work and that of the lesser organizations in such manner as will, without violation of ethics, increase the standing and emoluments of the profession as a whole.

(*c*) Meetings to be held biennially, at which officers will be elected, an executive committee chosen, policies determined and a budget of expenditures adopted.

(*d*) The Executive Committee will carry out the policies of the Council, administer its affairs, initiate new business and act in an advisory capacity to its lesser organizations. Its duties will also include the issuance to the varied membership of a bulletin, magazine or other form of publication.

(*e*) The work of the National Engineering Council to be financed by contributions from all engineering societies and allied technical organizations that are members of the Local Engineering Councils, the amounts of such contributions to be based upon the number of members in each.

These contributions may be financed by the different organizations in such manner as each shall deem best.

2. State Engineering Councils:

(*a*) Membership to consist of resident officers and members of boards of direction of the four Founder Societies, the American Society for Testing Materials, and such other national technical societies as may later be chosen to membership in the National Engineering Council and two members from each Local Engineering Council within the State in question.

(*b*) Powers and duties to be the safeguarding of engineers and the public in State legislation and the representing of engineers in welfare and public movements of state wide importance,

as well as the harmonizing of conflicting engineering interests and opinion between different localities of the state.

(*c*) Meetings to be held at least annually upon call of the officers of the Council.

(*d*) Work to be handled in such manner as may be determined by each State Council in question.

(*e*) Work to be financed by contributions from the Local Engineering Councils within the State, secured by such individual assessments as may locally be agreed upon.

3. Local Engineering Councils:

(*a*) Membership to consist of one or more members to be chosen by each of the local engineering societies and technical associations that are subsidiary to the national organizations forming the National Engineering Council, together with representatives from such allied technical organizations as each Local Engineering Council shall see fit to admit to its deliberations.

(*b*) Powers and duties to be the co-ordination of the work of the various local organizations represented in its membership, their representation in all local public affairs, the arrangement for joint meetings, both technical and non-technical, and the handling of all such general business as may be delegated to it by its component societies.

(*c*) Meetings to be held at such times as each Local Engineering Council may determine.

(*d*) Each council to be given the greatest possible latitude in originating its activities and handling its own affairs, consistent with the welfare of its members and the objects and procedure of the National and State Councils with which it affiliates in organization.

(*e*) All work and expenditures to be financed locally in such manner as the component organizations may decide. This does not preclude the national engineering organization from rebating a portion of the dues of their local members for this specific purpose.

Comments.—It is assumed that the best possible organization for the betterment of the engineering profession is one in which each engineer or technical man among the 50 000 or more to be embraced within it shall be given full opportunity to make his ideas, power and influence felt for the promotion of both his own and the common good. Therefore, the most important organizations from this point of view are the many local associations or chapters of the National Societies and the Local Societies of one kind or another at whose meetings members may become acquainted, exchange views and be of mutual aid to each other professionally. It is upon this foundation that is to be raised the superstructure of the several councils herein outlined.

It is recognized that, owing to the dissimilarity of interests in various localities, it would be impracticable for the National

Engineering Council to attempt to exercise authority or even general supervision over the activities of the local work. It can at best act only as an advisor and disseminator of information concerning mutual interests.

If some such organization as that here outlined shall be undertaken, it will probably follow that in some states no need will be felt for State Engineering Councils, and in some cities and localities there will be no Local Engineering Councils formed. If this assumption is correct it would be unwise for the Founder Societies and parent organizations to attempt to finance anything more than the expenditures of the National Engineering Council.

It is believed that the adoption of this plan would properly establish the National Engineering Societies as a dominating influence in the several councils, at the same time leaving each of them free to continue or modify its present provision for local associations or chapters as it shall see fit, as well as to handle its own business independently of all other Societies and in its own way.

Attention is called to the provision whereby representation in National and State Engineering Councils is based upon geographical rather than numerical considerations, it being held that the resulting value of a meeting like that of the National Engineering Council depends upon the value and variety of ideas elicited in discussion rather than upon the overpowering presence of a large number of people with but one idea in common. However, since there will of necessity be a greater number of Local Engineering Councils in the more populous communities, such communities will enjoy a greater though not preponderating representation in the meetings of the National Engineering Council.

Question may be raised as to whether "State Councils" as herein proposed would be preferable to "District Councils", which latter might include within their geographical boundaries portions of several adjoining States, thus bringing into one district members resident in neighboring cities with allied interests. Your Committee believes that such a question as this must be decided later and that either form of organization would be adaptable to the general scheme.

The Committee does not present this outline as a completely digested plan in all of the minor details, but with the idea of showing that the present directors and officers of the National Societies can be simply and easily formed into a united Engineering Council, to which can be added proper representation from State, Regional, or Local Associations in such a way as not to deprive National Societies and their Corporate Members of their proportionate and reasonable influence and control.

APPENDIX B

Recommendations for Internal Improvement of the American Society of Civil Engineers As Proposed by the Committee on Development

I. Recommendations in Report which are already in progress and do not require Constitutional Changes:

A. 1.—Local Sections hold not less than four meetings per year.
A. 2.—Monthly Proceedings include Editorial work, Abstracts and Reviews.
A. 4.—Co-operation with Specialized Engineering Societies and other Organizations.
A. 5.—Co-operation with American Engineering Standards Committee.
D. 1.—Definition of Engineering.
D. 2.—Code of Ethics.
D. 3.—Engineering Education, Standing Committee.
D. 6.—Washington Office and Legislation generally.
D. 7.—Public Service for the Engineer.
D. 8.—Patent Law, its Correction and Improvement.
D. 9.—Co-ordination of Government Activities, Federal Department of Public Works.

II. New Recommendations in Report not yet taken up by the National Societies or Engineering Council and which do not require Constitutional Changes:

A. 1.—That periodic joint meetings of the four National Societies be encouraged.
A. 2.—Program for papers announced for the season.
A. 5.—Book of recommended principles of practice.
D. 4.—Arbitration and expert testimony.
D. 5.—Publicity in standard Non-Technical Magazines.
D. 10.—Industrial affairs. Study of Industrial Problems.
B. 8.—Ground floor of Society house fitted up.
B. 7.—Compilation of Professional record of Members.
B. 5.—Young men to be encouraged in various ways. Specialized Student Organizations disapproved. General Societies advocated.

III. Recommendations in the Committee Report requiring Constitutional Changes:

A. 1. —Semi-Annual Meetings to be increased to four.
A. 1. —That fortnightly meetings of the Parent Society be discontinued.
A. 3. —Standing Committees of Three on each Engineering Subject.
A. 3. —Standing Advisory Committee on Welfare.
A. 5. —Technical Editorial Staff under direction of Publication Committee.

B. 1. c.—Geographic Districts divided into subdivisions containing Local Sections.
B. 1. b.—Every Member be assigned to a Local Section.
B. 1. d.—Local obligation to affiliate with other Technical Societies.
B. 1. e.—Directors elected by Corporate Members.
B. 1. e.—District Nominating Board formed, one delegate from each section.
B. 1. f.—Representative of each district elected by Corporate Members resident in district.
B. 1. g.—District may elect a non-resident Director.
B. 1. i.—Uniform proportion of dues allotted to each Local Section.
B. 1. j.—Conference of Representatives of Local Sections at Annual Conventions where allowed.
B. 1. k.—Present Nominating Committee abolished and general Officers nominated at above conference.
B. 1. l.—Director must visit each Local Section in his district once a year without expense to the Society, except in exceptional cases allowed by Board of Direction.
B. 2. a.—All Membership applications referred to Local Sections as well as Board of Direction.
B. 2. b.—Honorary Members. Distinguished persons not practicing profession.
B. 2. c.—Member must have been an Associate Member for two years.
B. 2. c.—"Responsible charge" for Member greater than for Associate Member.
B. 2. c.—Requirements for Junior deducted from Member's requirements.
D. 11. —Development Committee recommends no individual Membership in National organizations.
B. 2. c.—Grade of Fellow terminated; new "Fellow" established.
B. 2. c.—Fellow defined as a co-operating scientist.
B. 2. c.—Grade of Affiliate established for persons in commercial pursuits with Engineering knowledge.
B. 2. c.—Associate grade to be discontinued.
B. 2. c.—Requirements for Junior, 4 years' practice for non-technical graduate under direction of a Corporate Member of the Society or of an engineer of equivalent qualifications, school being considered equal time equivalent. Age limit, 21 years.
B. 2. d.—Discipline for Members made more effective.
B. 3. —Dues adjusted to new activities. Budget Committee to report.
B. 6. —Annual Meeting Program outlined.

DISCUSSION ON THE REPORT OF THE COMMITTEE ON DEVELOPMENT*

By E. G. Walker, M. Am. Soc. C. E.

E. G. Walker,† M. Am. Soc. C. E. (by letter).‡—In putting forward the following criticisms of the final report of the Committee on Development, I wish to make clear at the outset that I am thoroughly in accord with the whole of the general principles of the various schemes laid down, and the writer considers that the carrying of them out will be of material advantage to the Society and to the Engineering Profession at large. There are a few points, however, which might be modified with advantage and it is to these points that the writer confines himself in the following notes. With the remainder of the details of the report he is in full agreement. The writer will consider the items in order.

Division B; Section 2, "Membership"; Paragraph *b*: The qualifications for the grade of Honorary Member of the Society are not altogether happy. The writer thinks it much more desirable to reserve the honor of admission to this grade to distinguished individuals who have rendered assistance in the development of civil engineering rather than to those who are in a position so to do if they want to. In regard to the second class, namely "persons eminent for science and experience in pursuits connected with the profession of a civil engineer", the writer does not see why men of this eminence in the United States or its possessions should be handicapped against those of foreign countries. The degree of eminence required for Honorary Membership should be extremely high and the practice of the Society so arranged that Honorary Membership should be the definite hallmark of the appreciation of American civil engineers of the services of the individual; whether he be of National or foreign extraction should have nothing to do with the case.

The writer believes Paragraph *c* to be a step in the right direction although he does not see why requirements for the grade of Junior should be deducted from the candidates's record in determining his eligibility for the grade of Member. Surely the simplest method of assessing a man's engineering qualifications is to review his technical career as a whole.

He disagrees with the proposal to use the term "Fellow" for the new grade of membership which is proposed. Among technical and scientific societies there is a great deal of confusion at the present time in the meaning of the terms used, but in general in English

* Continued from January, 1920, *Proceedings*.

† London, England.

‡ Received by the Secretary, January 22d, 1920.

speaking countries the term "Fellow" is understood to mean, especially in societies dealing with pure science, a man who is fully qualified for the highest grade of technical membership. In England, for example, the highest membership that is open to any scientist is Fellowship of the Royal Society, and practically all societies dealing with various branches of science—chemical, physical, medical, etc.—use the term "Fellow" in the same way. In such of these societies as have a grade of Member as well, the latter is usually a lower grade of technical membership or else a non-technical grade. In most engineering societies of which the writer has had experience, the qualifications which are laid down for this proposed new grade are exactly those which would, in other societies, admit to the grade of Associate, and in several of them the proposed new grade of Affiliate would be included as well.

He suggests, therefore, that it is in the interests of general uniformity of practice among scientific societies that the two proposed grades of "Fellow" and "Affiliate" should be merged into a new class of "Associate". There would be considerable possibility of harmful exploitation of professional qualifications, if such confusion as is likely to arise by a numerous new class of "Fellows" being created, should develop, and this I can best illustrate by an example. The writer has come across cases of men practising in England who have applied for membership in the American Society of Civil Engineers rather than the Institution of Civil Engineers because the standard required for membership of the former has been lower than that required by the latter. Men of this type usually join technical societies principally for the benefit which they consider will accrue to them from membership. Over here, as already explained, Fellowship of a society in a good many cases implies a high standard of technical qualifications and this is generally understood to be the case in most English-speaking places. It would be undesirable, therefore, that it should be possible for a man with lower technical qualifications such as are proposed for the new class to be able to imply by the use of the term "Fellow" that his technical qualifications are of a similar order to those of a Member of the Society.

Section 8, "Additional Facilities at Headquarters": The proposal for the development of club facilities at Headquarters is certainly a good one, and might well in future be developed still further. After all, the principal way in which men of any calling or profession can be got together in large numbers is by providing plenty of social facilities, and there is much more likelihood of being able to get into touch with large numbers of engineers and inducing them to take an interest in the technical development of the Society by providing such facilities, not only at the Headquarters of the Society, but at the various local Headquarters as well.

Division C: With the recommendations under this heading the writer is fully in accord. In the report of the Joint Conference Committee, however, in Section 2, Sub-section 11, there seems to be some doubt as to whether it is proposed to go on with the consideration of the development of a code of ethics. He certainly believes this to be a matter that requires considerable thought and discussion before it can be completely developed, and advocates that it should be gone ahead with.

Division D, Section 1: Of the four definitions of Engineering given in this Section the writer does not consider that (*d*) is a correct definition. It appears to him, generally speaking, that (*a*) is the definition and (*b*) and (*c*) are extended explanations thereof. The only suggestion he has to make is that the term "forces" should be introduced, for since engineering is concerned mainly with the application of mechanical principles and these involve static forces in addition to dynamic, it is hardly right that the definition should include only sources of power, that is the application of dynamic force. The modification to definition (*a*) therefore will read "Engineering is the science and art of directing the forces and sources of power in Nature to the use and convenience of man".

Section 3: It is very desirable to develop a Committee on Engineering Education on the lines laid down, but the great point that must not be lost sight of in the formation of such committees is to prevent them developing into an academic committee of teachers. Such men are most undoubtedly not people to whom recommendations on engineering education can be entrusted. At the same time, it is very desirable that they should have a voice in the proceedings in order that the Committee may have the advantage of appreciating their point of view.

The Report of the Sub-committee on Budget shows very definitely that these proposed developments of the activities of the Society will involve increase of cost, and this increase will probably get greater as time goes on. By far the greater part of the development is work which will benefit exclusively members of the Society resident either in the United States or in places which are governed directly or indirectly by the United States Government. The Society has a comparatively large membership among engineers in foreign countries. These men derive their sole benefit from the Society through technical connection with it, and it therefore does not seem fair to expect them to pay the same increase on their subscriptions as members resident in the United States, inasmuch as they will not get, by any means, the same share of the benefits accruing from the new developments: the writer submits, therefore, that in settling on the new rates of subscription a differentiation should be made in favor of foreign members.

ITEMS OF INTEREST

The Committee on Publications will be glad to receive communications of general interest to the Society, and will consider them for publication in *Proceedings* in "Items of Interest". This is intended to cover letters or suggestions from our membership covering matters which are not of a technical character. Such communications, however, must not be controversial or commercial.

NATIONAL SERVICE COMMITTEE OF ENGINEERING COUNCIL

In response to frequent expressions of need, Engineering Council announces the establishment of a National Legislative and Departmental Information Service for engineers in all branches of the Profession. Information relative to engineering statistics, research, and construction, as well as of matters before Congress involving engineering considerations, will be furnished without charge by addressing the National Service Committee, M. O. Leighton, Chairman, 502 McLachlen Building, Washington, D. C. The National Service Committee also announces that its office at Washington is open to members of the Society at all times, and that accommodations can be had there at short notice for committee meetings of the Society, or of any organization in which the Society is interested, which may be held in Washington.

Conference of Members of Governing Boards of National Societies

At the instance of Engineering Council, members of the Governing Boards of the four Founder Societies and the American Society for Testing Materials, met in Joint Conference in the Engineering Societies Building, New York City, in an all-day session on January 23d, 1920.

The meeting was called to order by Past-President D. S. Jacobus, of Engineering Council, in the absence on account of illness of J. Parke Channing, Chairman. There were 72 officials present, as follows: Representing the American Society of Civil Engineers, 22; representing the American Institute of Mining and Metallurgical Engineers, 11; representing the American Society of Mechanical Engineers, 17; representing the American Institute of Electrical Engineers, 10, and representing the American Society for Testing Materials, 12. There were also present 23 others, including Trustees of the United Engineering Society, members of Engineering Council, and of the Joint Conference Committee. Mr. A. R. Ledoux, Vice-President, American Institute of Mining and Metallurgical Engineers, was elected Chairman of the Conference, and A. D. Flinn, Secretary of Engineering Council, was elected Secretary.

The following three resolutions, considered as recommendations to be submitted to the Governing Boards of the member Societies, were adopted:

"*Resolved:* That the amount contributed for Engineering Council by each Founder Society shall be $5 000 for the year 1920, in place of $3 000 as now provided, and by the American Society for Testing Materials, $1 000 instead of $600."

"*Whereas,* the American Society of Mechanical Engineers and the American Institute of Electrical Engineers have adopted in principle the essential recommendations contained in the report of the Joint Conference Committee of the four Founder Societies, and

"*Whereas,* it appears probable that the other Founder Societies will shortly also adopt the principles of this report, and

"*Whereas,* it would be most unfortunate to permit certain welfare measures of importance alike to engineers and to the public to be interrupted through lack of necessary immediate financial support, be it

"*Resolved:* By this Joint Conference of the governing bodies of the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, and the American Society for Testing Materials that appeals for contributions of $2 per person for the support of such welfare work during the interval before the recommendations of the Joint Conference Committee shall have been made effective, be sent at their discretion by the governing boards of the societies represented at this conference, to members of all grades, except juniors and student members, and be it further

"*Resolved:* That the appeal make clear the fact that unless engineers lend financial support immediately, the public welfare work of engineers will be seriously discredited, and be it further

"*Resolved:* That if the amount received by each society in response to the appeal be in excess of its appropriation voted for Engineering Council, such excess shall be appropriated by each society to Engineering Council or its successor."

"*Whereas,* this Conference of national engineering societies has considered the recommendations of the Joint Conference Committee of the four Founder Societies, therefore, be it

"*Resolved:* That the Conference adopts in principle that report and requests the Joint Conference Committee to call, without delay, a conference of representatives of National, local, State and regional engineering organizations to bring into existence the comprehensive organization proposed."

It was voted that if the Conference be called together again, it be called for a meeting in Chicago on April 20th, 1920.

Convention of National Public Works Department Association

The second general convention on a National Public Works Department was held in Washington, D. C., January 13th and 14th, 1920, and was attended by 95 delegates of 124 technical societies and

kindred business organizations, from all parts of the country. Alfred D. Flinn, Secretary of Engineering Council, appointed as delegate of the Society, reported as follows to the Board of Direction:

"Reports by the State branches of the National Public Works Department Association showed in the main that the campaign was progressing satisfactorily. Many congressmen and senators have been favorably interested. Engineers, architects and contractors are becoming supporters of the movement, and through them other professional men and business men are being informed. Greater New York was the most regrettable blank in the encouraging reports. The movement for a Public Works Department, and the Jones-Reavis bill providing therefor, have drawn forth much less criticism and opposition than was anticipated.

"Financial support for the campaign is the important present need. Organizations represented in the convention were requested to contribute $1 per member. The need for funds is acute.

"A campaign handbook was issued to the convention. In condensed form, convenient for reference, this pamphlet contains sound reasons and strong arguments for a Public Works Department.

"Congressman Reavis, of Nebraska, and Gen. R. C. Marshall, Jr., of the Construction Division, U. S. Army, made excellent addresses on the evening of January 13th. Governor Lowden, of Illinois, sent the manuscript of an address he had planned to deliver in person; it was read by Mr. Isham Randolph, of Chicago. Mr. M. O. Leighton, as Chairman of the Association, presided at the sessions of the convention.

"On the second day, representatives were given an opportunity to visit members of Congress and discuss the Public Works Department with them. As a result of these conferences, the opinion was expressed that the prospects for the passage of the bill by the present Congress (that is to say, before March 4th, 1921) are unusually good."

After discussion of the Jones-Reavis bill, the following resolution to define its position was adopted by the Conference:

"The following is hereby adopted as the attitude of the National Public Works Department Association with respect to Section 3 of the Jones-Reavis Bill:

"1. The National Public Works Department Association must, under its articles of organization, confine its efforts solely to the creation of a Department of Public Works.

"2. Section 3 of H. R. 6649—S. 2232 (the Jones-Reavis Bill) has nothing to do with public works. The only reason for its presence in the bill is that some departmental disposition must be made of the non-engineering bureaus in the Interior Department.

"3. It is manifest that the numerous organizations which become affiliated under the name of National Public Works Department Association for a common public works purpose do not, by so doing, commit themselves with respect to any other question, National or otherwise. Therefore each affiliated organization may have and is entitled to express its views as to said Section 3 of the bill without in any way qualifying its approval of the remainder of the bill.

"4. The National Public Works Department Association, as such, is therefore unable either to approve or to disapprove the specific assignments of bureaus in the said Section 3, and in advocating the bill before committees of Congress the agents of this Association are to be instructed to present this fact in an unmistakable way.

"5. The National Public Works Department Association suggests to all affiliated organizations that they present to Congress their own individual views with respect to said Section 3, either through the legislative agents of this Association or otherwise.

"6. The officers and directors of this Association are instructed to have the foregoing statements printed in suitable form and circulated as one of the campaign documents issued in support of this movement."

ACTIVITIES OF ENGINEERING COUNCIL

National Chamber of Commerce to Issue Referendum on Public Works Department

At a meeting of a Committee of the National Chamber of Commerce appointed at the request of Engineering Council to consider the advisability of submitting to referendum of the Chambers of Commerce throughout the country the question of a National Public Works Department, it was voted on January 19th, 1920, that such referendum should be sent. Messrs. Isham Randolph, D. Knickerbocker Boyd, M. O. Leighton, and L. W. Wallace appeared before the Committee, representing Engineering Council. F. H. Newell, M. Am. Soc. C. E., Ira N. Hollis, and J. Parke Channing were engineer members on the Chamber of Commerce Committee.

Military Affairs Committee Enlarged

The Military Affairs Committee of Engineering Council, the personnel of which has already been announced,* has been enlarged by the addition of the following men who have been in military service:

Lincoln Bush, M. Am. Soc. C. E.
John J. Carty, A. I. E. E.
H. S. Crocker, Vice-President, Am. Soc. C. E.
B. W. Dunn, A. S. T. M.
Arthur S. Dwight, A. I. M. E.
Alfred B. Fry, M. Am. Soc. C. E.
F. A. Molitor, M. Am. Soc. C. E.
G. R. Solomon, M. Am. Soc. C. E.
W. A. Starrett, M. Am. Soc. C. E.

Notes from National Service Committee

New Chief of Engineer Corps, United States Army

Col. Lansing H. Beach, M. Am. Soc. C. E., has been appointed by the Secretary of War as Chief of Engineers. While Col. Beach is

* *Proceedings*, Am. Soc. C. E., January, 1920, p. 61.

best known for the work he has done in connection with Mississippi River projects, he has had the varied service which comes to all Engineer Corps officers who have spent most of their lives in its service. He has done extensive engineering work on Great Lakes projects and was in charge of the important improvements of the harbors of Baltimore and Jacksonville. More recently he has been stationed at Cincinnati in charge of the construction of the system of locks and movable dams being constructed in the Ohio River. Col. Beach has been prominently identified with the development of inland waterways as a member of the Mississippi River Commission and as a member of the Board of Engineers for Rivers and Harbors and as an advisor to the Waterways Division of the Railroad Administration.

Board of Surveys and Maps

The provision made in the executive order* constituting a Board of Surveys and Maps that the Board was to set up a permanent organization was carried into effect on January 13th, 1920, when representatives from each of the member Departments met and elected O. C. Merrill, M. Am. Soc. C. E., Chief Engineer, Forest Service, Department of Agriculture, Chairman; William Bowie, M. Am. Soc. C. E., Chief, Division of Geodesy, Coast & Geodetic Survey, Department of Commerce, Vice-Chairman; and Col. C. H. Birdseye, Assoc. M. Am. Soc. C. E., Chief Geographer, Geological Survey of the Department of Interior, Secretary.

It is hoped that this concentration of mapping work will permit larger proportionate appropriations for the country's mapping program under the direction of the Geological Survey. In bringing this matter to the attention of the President, Engineering Council realized the great value of making reliable maps of the whole country available to every branch of the Engineering Profession in the simplest and most direct way. This will be accomplished through the central information office provided in the Geological Survey to receive and distribute Government and public map data.

Technical Work at the Bureau of Standards

Bulletins dated January 9th, 1920, on the progress of experimental work that has been started at the Bureau of Standards are as follows: (1) Accuracy of Electrical Measuring Instruments; (2) Electron Tubes in Radio Telephone Transmitting Sets; (3) Recent Radio Publications; (4) Industrial Safety Standards; (5) Measurement of Thermal Expansion of Various Materials; (6) Service Tests of Concrete Floor Treatments; (7) Consistency and Time of Set of Neat Cement Determined by New Method; (8) Slag as an Aggregate for Concrete; (9) Flat Slab Investigation; (10) Manufacture of Automo-

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* See *Proceedings*, Am. Soc. C. E., January, 1920, p. 59.

bile Crankshaft; (11) Investigation of Electric Welding; (12) Investigation of Chilled Iron Car Wheels.

Because of the current nature of these investigations the results are not generally put in printed form, but complete data on the results of the work to date is always available on application to the Bureau of Standards.

Annual Appropriations for Topographic Mapping

As the time for consideration of Departmental estimates for the next Sundry Civil Appropriation Bill approaches, the National Service Committee of Engineering Council, in co-operation with all State Geologists, is urging prominent engineers in every Congressional district to bring pressure to bear upon their Congressmen. This has been accomplished by selecting prominent engineers—members of the Founder Societies in each Congressional district—and urging them by direct appeal to request their Senato.s and Representative to support a \$600 000 appropriation for topographic mapping.

The State Geologists have co-operated by sending these engineers complete information of the local conditions, so that they may be thoroughly conversant with "back-home" requirements, and thus be more forceful with their men in Congress. Further, most of the State Geologists are endeavoring to get increased State appropriations for this important work, which will have to be matched by an equal Federal appropriation in most cases before they become available for expenditure.

The estimates submitted by the Secretary of the Interior call for an increased mapping program to cost \$600 000 annually, instead of \$500 000 which was last year's estimate. It will be recalled that the last Sundry Civil Appropriation Bill provided \$375 000 for topographic mapping, which was less by \$50 000 than pre-war annual appropriations for this work. This year's estimate contemplates a program that will complete topographic mapping in twelve years instead of one hundred years which will be required if the old appropriation is not increased.

Correction—Item Regarding Maj.-Gen. Black and Col. Abbot in Error

It is with regret that attention is called to two errors appearing in the item "Maj.-Gen. Black Retires from Active Service as Chief of Engineers" in *Proceedings* for Oct.-Nov.-Dec., page 939. The information there given was prepared from an article in the *Army and Navy Journal* of November 8th, 1919, stating that "during the World War he (Gen. Black) was awarded the D. S. M. for his service on the National Research Council during that period". This statement is incorrect. The actual fact is that the citation under which Gen. Black

was awarded the Distinguished Service Medal reads: "For especially meritorious and conspicuous service in planning and administering the engineer and military railway service during the war".

Attention is further called to the incorrect surname of "Francis" applied to Gen. Frederic V. Abbot, M. Am. Soc. C. E., also copied from the above-mentioned article. A letter from Col. Abbot concludes as follows:

"I have not been detailed temporarily as Acting Chief of Engineers, but by virtue of being the senior officer left on duty in the Office of the Chief of Engineers at Washington, I am *ex officio* Acting Chief of Engineers without any detail by anybody."

Research Graduate Assistantships at University of Illinois

The following extracts from a circular received from C. R. Richards, Dean and Director, College of Engineering and Engineering Experiment Station, University of Illinois, Urbana, Ill., describe the Research Graduate Assistantships offered by the University. There will be eight vacancies to be filled at the close of the current academic year.

"To assist in the conduct of Engineering Research and to extend and strengthen the field of its graduate work in Engineering, the University of Illinois maintains fourteen Research Graduate Assistantships in the Engineering Experiment Station. Two other such assistantships have been established under the patronage of the Illinois Gas Association. These assistantships, for each of which there is an annual stipend of $500 and freedom from all fees except the matriculation and diploma fees, are open to graduates of approved American and foreign universities and technical schools who are prepared to undertake graduate study in Engineering, physics, or applied chemistry.

"An appointment to the position of Research Graduate Assistant is made and must be accepted for two consecutive collegiate years, at the expiration of which period, if all requirements have been met, the degree of Master of Science will be conferred. Not more than half of the time of a Research Graduate Assistant is required in connection with the work of the department to which he is assigned, the remainder being available for graduate study.

"Nominations to these positions, accompanied by assignments to special departments of the Engineering Experiment Station, are made from applications received by the Director of the Station each year not later than the first day of March. The nominations are made by the Executive Staff of the Station, subject to the approval of the President of the University. Nominations are based upon the character, scholastic attainments, and promise of success in the principal line of study or research to which the candidate proposes to devote himself. Preference is given those applicants who have had some practical engineering experience following the completion of their undergraduate work. Appointments are made in the spring, and they become effective the first day of the following September. Vacancies may be filled by similar nominations and appointments at other times."

Engineering Congress at Batavia, Java

The General Engineering Congress* to be held at Batavia, Java, in May, 1920, has announced the following tentative programme:

May 8th.—Official Opening at the Palace (Government House) at Weltevreden, by His Excellency Count van Linburg Stirum, Governor-General of the Netherlands, East Indies, Patron of the General Engineering Congress; speech by the Burgomaster of Batavia; dinner at the Gardens, followed by a welcoming speech by the Chairman of the Local Committee.

May 9th.—Motor excursion through Batavia; reception by the Town Council, followed by a Concert at the Harmony Club and a social gathering in the evening.

May 10th.—Meetings of the Sections in the morning, to be followed by a Concert at the Concordia Club; lectures illustrated with lantern slides in the evening, followed by Governor-General's reception at the Palace.

May 11th.—Meetings of the Sections; Concert at the Concordia Club, and a Soirée at the Harmony Club.

May 12th.—Visits to the Museum, the Topographical Institute, etc. In the evening, readings by natives on Native Development, Manner of Life, etc.

May 13th.—Meetings of the Sections; Concert at the Concordia Club; gala Symphony Concert at the Concordia Club in the evening.

May 14th.—Meetings of the Sections and Concert at the Concordia Club; theatre in the evening.

May 15th.—Meetings of the Sections; final meeting, speeches by the Honorary Presidents and foreign delegates; Congress dinner, followed by a Ball.

At a meeting of the Board of Direction, E. A. Silagi and A. Groothoff, Assoc. Members, Am. Soc. C. E., were appointed delegates to represent the Society at the Engineering Congress.

EUROPEAN NOTES

The following notes relative to reconstruction, etc., in Belgium and France, and industrial progress, etc., in Great Britain and elsewhere, have been contributed by W. E. Woolley, Assoc. M. Am. Soc. C. E., of London, England, who is also a Corresponding Member of the Association of Liége (Belgium) Architects.

National Congress of Belgian Architects

The ninth National Congress of Belgian Architects convened on December 14th, 1919, at the Palais de la Bourse, Brussels. The President, M. Mankels, referred to the part played by Belgian architects

*See *Proceedings*, Am. Soc. C. E., April, 1919, p. 422.

during the War, and named those who had fallen on the battlefield, and those who had died in other ways for their country.

M. Arthur Snyers, President, Association des Architects de Liége, discussed the question of the architect's diploma, which had been agitated for since 1874 in the various professional organs and congresses. He said it was not sufficient that the architect should have indispensable knowledge, it is necessary in addition that he be an artist. Public authorities appear to welcome such measures, but the diploma, which would be recognized by law, has not, however, been created. A resolution inviting the authorities to immediately create an architect's diploma, which is indispensable to the reconstruction of the country, and charging the Federation to enter immediately into co-operation with the Government for the realization of this measure, was unanimously adopted.

Was it necessary to rebuild Ypres as it was before the War? asked M. L. David. He thought not. The economic conditions have changed, the destroyed towns cannot be as they were. Plans and the procedure of reconstruction should be adapted to the exigencies of modern life and social evolution, but preserving the principal ruins—The Halles, St. Martin, St. Pierre—as a testimony to German vandalism and to the endurance and the courage of the Allies.

M. Vinck announced that the Railway Department, also the Departments of Science and Arts, will enforce stipulations to obtain in future an artistic character for schools, stations, etc. Competitions will be organized for this purpose.

With one exception, all were in favor of the reconstruction of Ypres in modern style, the ruins of the Halles (Cloth Hall) and of St. Martin only to be preserved.

Bush Company Purchases Aldwych Site

For some time it has been known, according to the London *Daily Chronicle,* that the Aldwych Island site in the Strand had been acquired by the Bush Company, Ltd. (Bush Terminal Company of New York). The lease with the London County Council has been signed.

It is proposed to erect a £2 000 000 building.

Battlefield Tourist Hotels

M. Claveille, French Minister of Public Works, has introduced in the Chamber of Deputies a bill for the organization of the devastated districts.

The Bill authorizes a loan of £1 200 000 for building hotels, restaurants, and camps, and providing means of transport for the convenience of visitors.

Wireless Telephony

Experiments are proceeding with the object of increasing the range of wireless telephony, and eliminating, according to the London *Daily Chronicle,* interference with conversation conducted by means of this instrument.

Recently a series of tests were carried out by the Marconi Co. between their works at Chelmsford and a point near Amsterdam, in which Dutch experts took part. The results obtained are stated to have been in every way satisfactory.

Conversations have taken place with America, but they were simply experimental.

At the present moment, the device is being employed in districts unequipped with the ordinary telephones, among the purchasers being the Chinese, who have acquired a large number of sets.

BRIEF NOTES

The U. S. Forest Service announces that damage by forest fires in the eastern section of the country, and likewise in Mississippi Valley, is far in excess of that in the West. The average annual loss, for the three-year period ending 1918, due to forest fires in the entire country was $20 727 917. The average of total area burned annually was 13 969 331 acres. The region lying to the east and south of Ohio, Kentucky, and Tennessee included 47% of the total area burned, and sustained 32% of the total damage. In the Mississippi Valley, the damage was 61% of the total.

The Director of Sales of the War Department announces that the Ordnance Department Salvage Board, through the New York District Office, is offering for sale by negotiation the land, buildings, and equipment of a Sulphuric Acid Plant at Mount Union, Pa.

What is said to be the world's largest sale of commercial airplanes was made at the recent aeronautical show in Chicago. One company sold 440 planes to B. L. Brookins of Tulsa, Okla., for $2 500 000. Airplanes are now in great demand in oil fields, the operators using them to reach new fields when a "strike" is made. Directors of the show estimated the total sales of the week at 1 700 planes.

According to the Comptroller of the Currency, the earnings of 8 000 banking institutions in the country last year exceeded all previous figures and will approximate $1 000 000 000 gross and not far from $300 000 000 net. This record is attributed largely to the high efficiency and invaluable aid of the Federal Reserve system.

C. A. Prouty, of the Interstate Commerce Commission, predicted before the House Appropriations Committee at Washington, D. C., that the valuation of railroads, begun five years ago, would be completed

by the Commission within two years. The cost will be approximately $21 000 000.

The Secretary of War has asked the House Appropriations Committee for an increase in appropriations for the maintenance of the Panama Canal from $12 000 000 to $18 000 000.

The Salvage Division, Office of Director of Storage of the War Department, reports that sale of waste materials and unserviceable property from December 1st to December 18th, 1914, amounted to $846 756—an increase of 86% over sales for a corresponding period of November. It was estimated that final returns will show such sales during December amounted to approximately $1 500 000, exceeding all previous records.

The Director of Sales of the War Department announces offer to sell to State, municipal and county institutions any commodities or materials embraced in its surplus stock at a discount of 10% from prices prevailing in the Army Quartermaster retail stores or prices at which those institutions can purchase similar commodities in similar quantities through established trade channels.

The Secretary of War has recommended to Congress legislation authorizing an army of approximately 275 000 officers and men for remainder of fiscal year. This number is 100 000 in excess of the peace-time army permitted by the National Defense Act.

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, New Year's Day, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 6 P. M.

FUTURE MEETINGS

March 3d, 1920, 8.30 P. M.—This will be a regular business meeting. A paper by Frank G. Jonah, M. Am. Soc. C. E., entitled "The 'Light Railways' of the Battle Front in France," will be presented for discussion.

This paper was printed in the *Proceedings* for January, 1920.

March 17th, 1920, 8.30 P. M.—A meeting will be held on this evening as usual, and announcement of the programme which is in the hands of the Programme Committee for Second Meeting of Each Month, will be made later.

April 7th, 1920, 8.30 P. M.—A regular business meeting will be held, and a paper by Herbert C. Keith, M. Am. Soc. C. E., entitled "A Novel Method of Repairing a Swing Bridge," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

April 21st, 1920, 8.30 P. M.—The usual meeting will be held and announcement of the subject and speaker will be made later.

ENGINEERING SOCIETIES EMPLOYMENT BUREAU

Engineering Societies Employment Bureau, established December 1st, 1918, as an activity of Engineering Council, is managed by a board made up of the Secretaries of the four Founder Societies, funds for its maintenance being provided by these Societies. The work of the Bureau since its inception has been largely in the line of securing employment for men retiring from government war service. Members of the American Society of Civil Engineers who desire to register with this Bureau should apply for further information, registration forms, etc., to Walter V. Brown, Manager, Engineering Societies Employment Bureau, First Floor, Engineering Societies Building, 29 West 39th Street, New York City.

SEARCHES IN THE LIBRARY

As the Library of the American Society of Civil Engineers has been merged in the Engineering Societies Library, requests for searches, copies, translations, etc., should be addressed to the Director, Engineering Societies Library, 29 West 39th Street, New York City, who will

gladly give information concerning the charges for the various kinds of service. A more comprehensive statement in regard to this matter will be found on page 21 of the Year Book for 1919.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion will be published as heretofore in *Proceedings,* and set down for presentation to a future meeting of the Society, and, on these, oral discussion, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 35 of the Year Book for 1919.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association, Organized 1905.

M. M. O'Shaughnessy, President; Nathan A. Bowers, Secretary-Treasurer, 502 Rialto Building, San Francisco, Cal.

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Engineers' Club, 57 Post Street, on the third Tuesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at noon, every Wednesday, at the Engineers' Club, where special tables are reserved for members and guests of the Association.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association, Organized 1908.

W. C. Huntington, President; A. N. Miller, Secretary-Treasurer, 1400 West Colfax Avenue, Denver, Colo.

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesday, at 12.30 P. M., at Daniels and Fisher's.

Visiting members are urged to attend the meetings and luncheons.

Atlanta Association, Organized 1912.

V. H. Kriegshaber, President; Howard L. Stillwell, Secretary-Treasurer, 533 Trust Co. of Georgia Bldg., Care, Southeastern Underwriters' Association, Atlanta, Ga.

Informal luncheons are held for members of the Association on the last Monday of each month, at 12.30 P. M., to which visiting members of the American Society of Civil Engineers will be welcomed. The place is not fixed, but this information will be furnished on application to the Secretary.

Baltimore Association, Organized 1914.

H. G. Perring, President; Charles J. Tilden, Secretary-Treasurer, The Johns Hopkins University, Baltimore, Md.

Cleveland Association, Organized 1914.

W. P. Brown, President; George H. Tinker, Secretary-Treasurer, 516 Columbia Building, Cleveland, Ohio.

The regular meetings of the Association are held on the second Wednesday of each month, at 12.15 P. M., in the Rooms of the Electrical League, on the Fourteenth Floor of the Statler Hotel. Luncheon is served at these meetings, and visiting members are invited to attend.

Connecticut Association, Organized 1919.

C. M. Saville, President; R. J. Ross, Secretary, Municipal Building, Hartford, Conn.

The Annual Meeting of the Association is held in April. The Association holds fortnightly meetings alternating between Hartford and New Haven, Conn. These meetings are informal luncheon gatherings held usually at noon on Saturday, a notice being mailed to each member calling attention to the date, time, place, and subject for discussion. Members are privileged to invite guests regardless of their affiliation as engineers. No set speeches are scheduled, but certain members are asked to be prepared to present the assigned subject and lead in a general discussion.

Detroit Association, Organized 1916.

T. A. Leisen, President; Clarence W. Hubbell, Secretary, 2348 Penobscot Building, Detroit, Mich.

The regular meetings of the Association are held on the second Friday of December, April, and October, the last being the Annual Meeting.

District of Columbia Association, Organized 1916.

David S. Carll, President; James C. Van Wagenen, Secretary-Treasurer, 719 Fifteenth Street, N. W., Washington, D. C.

Duluth Association, Organized 1917.

G. A. Taylor, President; Walter G. Zimmermann, Secretary, Wolvin Building, Duluth, Minn.

The regular meetings of the Association are held at noon on the third Monday of each month (usually at the Kitchi Gammi Club), with luncheon, followed by a short business session and the reading of papers. Visiting members of the American Society of Civil Engineers can secure from the Secretary definite information relative to the meetings, at which they will be welcomed. The Annual Meeting is held on the third Monday in May.

(Abstract of Minutes of Meetings)

October 20th, 1919.—The meeting was called to order at the Kitchi Gammi Club; President G. A. Taylor in the chair; Walter G. Zimmermann, Secretary; and present, also, 14 members.

The minutes of the previous meetings were read and approved.

The Secretary read a resolution adopted by the Pittsburgh Association urging haste on the part of Engineering Council's Committee on Classification and Compensation of Engineers in completing and publishing its report. On motion, duly seconded, the resolution was ordered filed.

Mr. W. H. Hoyt presented a brief report of the meeting of the Committee on Development at Ann Arbor, Mich., September 22d to 25th, 1919, inclusive.

Adjourned.

November 17th, 1919.—The meeting was called to order at the Kitchi Gammi Club; President Taylor in the chair; Walter G. Zimmermann, Secretary; and present, also, 22 members.

President Taylor announced that Mr. Elbert H. Dresser had received notice of his election as a Member of the Society.

The minutes of the meeting of October 20th, 1919, were read and approved.

The Secretary read a letter from Mr. Harry Hawgood, of Los Angeles, Cal., Director of District No. 11, asking for an expression of preference from the Association in the matter of the place for holding the next Annual Convention of the Society at Los Angeles, Cal., or Houston, Tex. On motion, duly seconded, the Society was instructed to inform Mr. Hawgood that the Association favored Los Angeles as the meeting place.

A letter was read from Mr. M. O. Leighton, Chairman of the Engineers', Architects' and Constructors' Conference on National Public Works, at Washington, D. C., pertaining to the Jones-Reavis Bill providing for the creation of a Federal Department of Public Works, urging the Association, as well as all engineering societies and chapters, to do missionary work for this bill.

Mr. W. H. Hoyt announced that he had been appointed a member of the Executive Committee of this Conference, as well as Chairman for the State of Minnesota, and that through the Minnesota Joint Engineering Board, the necessary correspondence was already being carried on and that the Senators and Congressmen for Minnesota had been interviewed in regard to the bill.

After a general discussion of Mr. Leighton's letter, it was decided, on motion, duly seconded, that the matter be referred to Mr. Hoyt as State Chairman to ascertain why this letter by Mr. Leighton had been sent out in such a way as to render liable dissension in the Profession.

On motion, duly seconded, a committee of three bachelors was appointed to arrange for an entertainment or a party for the wives and sweethearts of the members.

Mr. W. L. Darling, the representative from the district on the Nominating Committee of the Society, presented statistics as to the number of Past Directors in the District No. 7 per each State and province and his reason for suggesting the nomination of Anson Marston, Dean of Engineering, Iowa State College, as Director of the District to be elected at the Annual Meeting of the Society in January, 1920. Mr. Darling gave a detailed account of the professional record of Dean Marston and also of Arthur P. Davis, the nominee for President of the Society.

Adjourned.

December 15th, 1919.—The meeting was called to order at the Kitchi Gammi Club; President Taylor in the chair; Walter G. Zimmermann, Secretary; and present, also, 22 members and 2 guests.

The minutes of the meeting of November 17th, 1919, were read and approved.

Col. Pope reported that the Special Entertainment Committee, consisting of himself, and Messrs. Bryant and Cokefair, had consulted with various members of the Association as to the proposed entertainment for wives and sweethearts, and suggested that it be in the form of a dinner and theatre party. On motion, duly seconded, the Committee was authorized to make the necessary arrangements for such a programme.

Mr. D. A. Reed presented the question of the formation of a City Planning Committee for the City of Duluth, stating that the idea of the Committee of the Commercial Club which had the matter in hand was to establish a Board of City Planning with a paid executive staff and engineering department and suggesting that the members of the Association have the matter in mind so as to be able to make suggestions when the opportunity arose. The matter was discussed further by Messrs. Coe, Hawley, and Stack.

A paper on the "Suburban Transportation System for the City of Duluth" by Mr. H. C. Ash was presented by the author.

Mr. W. L. Darling spoke on the absurdity of the statements recently made by an astronomer in California regarding the disaster predicted for the earth between December 17th and 23d, 1919, on account of the proximity of certain planets to the sun.

Adjourned.

January 12th, 1920.—The special meeting was called to order at the Duluth Commercial Club; President Taylor in the chair; Walter G. Zimmermann, Secretary; and present, also, 23 members and 1 guest.

President Taylor stated that the object of the special meeting was to consider the report of the Committee on Development and decide what if any action should be taken by the Association in regard to it and the nine questions submitted to the Board of Direction with the report, prior to the Annual Meeting of the Society.

The Secretary presented a letter from President Taylor to the Board of Direction of the Society asking why the nine questions previously mentioned had not been submitted to the membership of the Society and Secretary Hunt's reply acknowledging receipt of the letter and stating that the matter would be referred to the Board Meeting of January 19th, 1920.

Mr. W. H, Hoyt, the representative of District No. 7 on the Development Committee, read and commented on the nine questions, which he stated had been drawn up by a Sub-Committee of the Committee consisting of Mr. Richard L. Humphrey of Philadelphia, Pa., and himself.

Communications were read from the Colorado, Nebraska, Northwestern and Philadelphia Associations, pertaining to the action taken by these Associations in order to secure prompt action on the report.

A letter from Mr. W. H. Woodbury was also read suggesting that the Association send either an emphatic statement or a delegate to the Annual Meeting of the Society with a view to urging prompt action on the Development Committee's report.

Mr. O. H. Dickerson stated that he had recently attended a special meeting of the Northwestern Association at St. Paul at which the Development Committee report had been discussed and at which that Association had appointed a delegate to the Annual Meeting.

On motion, duly seconded, the President was instructed to appoint a delegate from the Association to attend the Annual Meeting in New York City and that this delegate be instructed that it is the view of the Association that the nine questions, regardless of their merit, should be submitted to the membership of the Society in order to give them the opportunity of expressing their views thereon.

Illinois Association, Organized 1916.

Albert Reichmann, President; W. D. Gerber, Secretary-Treasurer, 913 Chamber of Commerce, Chicago, Ill.

The regular meetings of the Association are held on the second Monday of March, June, September, and December, the last being

the Annual Meeting. The hour and place of meetings are not fixed, but this information will be furnished on application to the Secretary.

(Abstract of Minutes of Meeting)

December 19th, 1919.—The Annual Meeting was called to order at the Engineers' Club; President H. J. Burt in the chair; E. S. Nethercut, Secretary; and present, also, 37 members and guests.

The minutes of the previous meeting were approved without reading.

The Secretary-Treasurer presented his annual report, and, on motion, duly seconded, Mr. Albert Reichmann was appointed to audit the books of the Treasurer.

On motion, duly seconded, the following officers were nominated and elected: President, Albert Reichmann; Vice-President, A. J. Hammond; and Secretary-Treasurer, W. D. Gerber.

The President declared the members of the Executive Committee for 1920 to be: President, Albert Reichmann; Vice-Presidents, A. J. Hammond and C. B. Burdick, Past-President, H. J. Burt; and Secretary-Treasurer, W. D. Gerber.

Mr. A. J. Hammond, Chairman of the Special Committee on Arrangement and Co-operation between the Association and the Western Society of Engineers, presented the following recommendations as the unanimous report of the Committee:

"1. It is deemed desirable and advisable that the Illinois Association of the American Society of Civil Engineers co-operate in every way with the Western Society of Engineers for the benefit of the Engineering Profession.

"2. That arrangements be perfected with the Western Society of Engineers whereby the Secretary of that Society may assume the clerical duties required to take care of interests of the Illinois Association.

"3. That the National Society, American Society of Civil Engineers, be requested to divert sufficient funds from the general receipts of the Society to pay the legitimate clerical expense involved in Item 2.

"4. All Illinois members of the American Society of Civil Engineers shall automatically become members of the Illinois Association. They should all be urged to be members of the Western Society of Engineers.

"5. The American Institute of Electrical Engineers and the American Society of Mechanical Engineers now have arrangements made with the Western Society of Engineers which provide for joint meetings and other privileges. Similar co-operation or closer connection also should be made by the Illinois Association of the American Society with the Western Society of Engineers.

"6. The employment bureau feature of the New York quarters of the National Society, to be featured by the Illinois Association, should also be in conjunction with the Western Society of Engineers.

"7. Stated meetings are to be arranged to be held at the Western Society of Engineers' rooms, possibly bi-monthly. Papers which are to be presented to the National Society, New York, may also be presented and discussed at the same time as presented in New York, at these meetings. These meetings to be held in conjunction with the Western Society of Engineers.

"8. That the initiative be taken by the Illinois Association of the American Society of Civil Engineers towards a more active and closer relationship and co-operation with the Western Society of Engineers and also towards perfecting the same relationship with the other National Societies.

"9. We further recommend that officers of the Association take immediate steps towards carrying out the recommendations of the Committee."

Mr. J. W. Alvord, Chairman of the Special Committee appointed by the Board of Direction, discussed the report of the Development Committee and outlined the recommendations of the Special Committee to the Board of Direction. The report was further discussed by Messrs. Reichmann, Hatch, Pendleton, Nethercut, and Gen. Bixby.

A notice by Mr. Hammond recommending the adoption of the report of the Special Committee on Arrangements and Co-operation between the Association and the Western Society of Engineers, was discussed by Messrs. Alvord, DeBerard, Arnt, Healey, and Col. Millis.

On motion, duly seconded, the report was accepted, and the subject was ordered to be presented at a luncheon talk at the Chicago Engineers Club.

Adjourned.

Louisiana Association, Organized 1914.

Arsène Perrilliat, President; Eugene F. Delery, Secretary, 503 City Hall Annex, New Orleans, La.

The regular meetings of the Association are held at The Cabildo, New Orleans, La., on the first Monday of January, April, July, and October.

Nebraska Association, Organized 1917.

Clark E. Mickey, President; Homer V. Knouse, Secretary-Treasurer, 200 City Hall, Omaha, Nebr.

Regular meetings of the Association are held on the first Saturday of each month, except July and August, and at such places as may be appointed from time to time by the Executive Committee. The Annual Meeting is held in Lincoln, Nebr., on the second Friday in January.

Visiting members of the Society are especially urged to communicate with the Secretary when in the city.

(Abstract of Minutes of Meeting)

January 10th, 1920.—The Annual Meeting was called to order at the Hotel Delavan, Lincoln, Nebr.; in the absence of the Acting President and the Vice-President, William Grant was elected President *pro tempore;* Homer V. Knouse Secretary; and present, also, 11 members.

Minutes of previous meetings were read and approved. Ballots for officers were canvassed, and the following declared elected: President, Clark E. Mickey; Vice-Presidents, Rodman M. Brown and John L. Hershey; Secretary-Treasurer, Homer V. Knouse.

The Treasurer's report was read and accepted.

A communication asking for support of Engineering Council was read, and the work and aims of the Council discussed. Upon motion, duly seconded and carried, the Secretary was instructed to collect $1.50 from each member of the Association who had not already contributed directly, such amounts to be forwarded to Engineering Council. A motion was adopted commending Engineering Council and expressing the desire to aid its work in every way possible, also urging the extension of its activities and the co-ordination of its work with other organizations.

Upon motion, duly seconded and carried, the President was instructed to appoint a Committee to select members to act as experts for the Publication Committee of the Society, as requested by the Secretary, Chas. Warren Hunt.

A motion was carried instructing the Secretary to advise Mr. H. Hawgood, Director of the Society, that, in response to his request for an expression of the Association on the place of meeting of the next Annual Convention of the Society, the preference was for Los Angeles, Cal.

At the meeting in the evening, the Secretary presented various communications in support of the movement for a National Public Works Department. Upon motion, duly seconded and carried, the President appointed Messrs. Letton, Davis and Mirick to draft resolutions endorsing the Jones-Reavis bill.

A complete set of resolutions was prepared and adopted, as follows:

"*Whereas,* the Nebraska Association of Members of the American Society of Civil Engineers, convened in Annual Meeting, have considered the report of the Committee on Development of the Parent Society, and

"*Whereas,* it is apparent that a great amount of study and careful consideration has been given to problems that confront the American Society of Civil Engineers in this period of reconstruction and readjustment, and that a large amount of time and effort has been devoted to the furtherance of this work, and

"*Whereas,* the members of this Association are fully cognizant of the efforts of the Committee on Development to place the activities of the American Society of Civil Engineers on a plane that will meet the present day needs of the Engineers of America, therefore be it

"*Resolved,* that this Association express their appreciation of the work of that Committee, and commend said report as being a most decided step forward in Society affairs, and be it further

"*Resolved,* that a copy of these resolutions be forwarded to the Secretary of the American Society of Civil Engineers with the request that same be published in the *Proceedings* of said Society."

The President announced the appointment of Messrs. Grant, Bruce, Hershey, Tracy, Magruder, Mirick and Bates on the Legislative Com-

mittee. On motion, duly seconded and carried, this Committee was instructed to consider matters then before the Constitutional Convention and report anything affecting engineers upon which the Association should exert its influence.

Upon motion, duly seconded and carried, the Secretary-Treasurer was instructed to levy an assessment of $2.00 per member to meet the expense of increased activities of the Association; also to submit to the Board of Direction of the Parent Society an amendment changing the date of the Annual Meeting of the Association from the second Friday to the second Saturday in January.

The President appointed Messrs. Edgecomb, Fulton and Davis as a Publicity Committee, following the adoption of a motion creating such a Committee.

The Secretary reported the action of Commissioner Zimman of the Building Department, Omaha, Neb., in requesting the Association to suggest an engineer for the office of Chief Engineer in the Building Department, and to support the establishment of an Advisory Committee to the Commissioner of Buildings to consist of an architect, a structural engineer, a contractor, and a layman.

Adjourned.

Northwestern Association, Organized 1914.

Ralph D. Thomas, President; W. N. Jones, Secretary, City Engineer's Office, City Hall, Minneapolis, Minn.

The meetings of the Association are held bi-monthly, alternating between St. Paul and Minneapolis, on the third Friday of each month. Information as to the time and place of such meetings will be furnished on application to the Secretary.

Philadelphia Association, Organized 1913.

S. M. Swaab, President; Henry T. Shelley, Secretary, 416 City Hall, Philadelphia, Pa.

The regular meetings of the Association are held at the Engineers' Club of Philadelphia, 1317 Spruce Street, on the first Monday in January, April, and October, the last being the Annual Meeting. Special meetings will also be held during the winter, in order to provide an opportunity for members to take a more active part in the work of the Association.

(Abstract of Minutes of Meeting)

February 2d, 1920.—A special meeting was called to order at the Engineers' Club, President S. M. Swaab, in the chair; Henry T. Shelley, Secretary; and present, also, 22 Members.

Mr. C. T. Chenery, Secretary of the National Public Works Department Association, addressed the meeting on the Jones-Reavis bill to create a National Department of Public Works. Mr. Chenery outlined the movement in behalf of the National Department of Public Works from 1884 to the present time. He convincingly presented the need for such a department and the efforts being made to make it a reality. A campaign was inaugurated to put the engineers of Philadelphia in line for the support of the bill.

A thorough discussion followed Mr. Chenery's address, participated in by Mr. Trautwine, Prof. Ketchum, Mr. Phillips and Mr. Humphrey. Mr. Humphrey presented a resolution, which was voted unanimously by the Association, as follows:

"*Whereas,* The great need for a department to be charged with the execution of public works has been for a long time apparent; therefore, be it

"*Resolved,* That the Philadelphia Association of Members of the American Society of Civil Engineers heartily endorses the proposed formation of a National Department of Public Works from the present Interior Department as contemplated by the Jones-Reavis bill and pledges to support this movement to the extent of its ability."

It was also voted to appoint a committee for the purpose of securing co-operative action with the Engineers' Club and other engineering societies for the support of the bill. The President appointed to this committee Prof. Ketchum, Mr. Trautwine and Mr. Humphrey, Chairman.

A communication with accompanying resolution received from the Joint Council of the Engineering Societies of San Francisco was presented to the Association for action. The communication and resolution requested support of Mr. Hoover for President. The Association voted to receive the communication, but did not deem it in order to take action.

A communication with accompanying resolution was received from the Municipal Engineers of Philadelphia in regard to efforts of the Architects' Association to induce the Governor of the State to appoint an architect instead of a civil engineer to design the proposed bridge over the Delaware River. The Association adopted, on recommendation of Mr. Jonathan Jones, the following resolution:

> "*Whereas,* The local press of January 26, 1920, has published extracts from a letter stated to have been forwarded to the Governor of the State of Pennsylvania by the Secretary of the Pennsylvania State Art Commission, in which it is urged that an architect rather than an engineer be appointed to direct the design of the Delaware River bridge; therefore be it
>
> "*Resolved,* By the Philadelphia Association of Members of the American Society of Civil Engineers, at a special meeting held February 2d, 1920:
>
> "1. That this Association reiterates its judgment as expressed in a resolution adopted November 24th, 1919, that 'safety to human life and the proper expenditure of public funds require that the design and erection of such structures be under the responsible charge of competent and experienced civil engineers, especially skilled and trained for that class of work'.
>
> "2. That this Association desires to see full consideration given to the proper placing and the aesthetic treatment of the Delaware River bridge by a qualified architectural consultant, or consultants, preferably chosen by, but certainly responsible to, the Chief Engineer, who alone can finally harmonize the claims of beauty and art with the primary necessities of structural safety and reasonable cost."

On motion of Mr. Humphrey it was voted that the President and Secretary be directed to take up with the Engineers' Club and other Engineering Societies the appointment of a Committee to place before the proper authorities the desirability of appointing a competent civil engineer for the design and construction of the Delaware River bridge.

Adjourned.

Pittsburgh Association, Organized 1917.

Morris Knowles, President; Nathan Schein, Secretary-Treasurer, 426 City-County Building, Pittsburgh, Pa.

The Annual Meeting of the Association is held on the first Monday in October. The time and place of other meetings are not fixed, but this information will be furnished on application to the Secretary.

Portland (Ore.) Association, Organized 1913.

E. Burslem Thomson, President; C. P. Keyser, Secretary, 318 City Hall, Portland, Ore.

The Annual Meeting of the Association is held on the second Friday in January. Other meetings are called by the President and are usually convened on Friday evenings. The place is not fixed, but this information may be obtained on application to the Secretary. All members of the American Society of Civil Engineers are cordially invited to attend the meetings.

St. Louis Association, Organized 1888 (Constitution Approved by Board, 1914).

Edward E. Wall, President; C. W. S. Sammelman, Secretary-Treasurer, 300 City Hall, St. Louis, Mo.

The Annual Meeting of the Association, for the election of officers and for the transaction of business, is held on the fourth Monday in November. Two meetings each year, for the presentation and discussion of technical papers, are held in the Auditorium of the Engineers' Club of St. Louis and are open to members of the Associated Societies. Other "get-together" meetings are held regularly for dinner or luncheon on the fourth Monday of each month except July, August, and November.

San Diego Association, Organized 1915.

W. C. Earle, President; R. C. Wueste, Secretary-Treasurer, Bonita, Cal.

Seattle Association, Organized 1913.

L. M. Grant, President; G. A. Collins, Secretary, 1317 L. C. Smith Building, Seattle, Wash.

The regular meetings of the Association, with luncheon, are held at the Engineers' Club, Arctic Building, Third Avenue and Cherry Street, at 12.15 P. M., on the last Monday of each month. Informal luncheons are also held at 12.15 P. M., every Monday at the Engineers' Club.

Special evening meetings are held from time to time for the purpose of discussing important topics, and information concerning these meet-

ings may be had by addressing the Secretary. All members in any grade of the American Society of Civil Engineers are cordially invited to attend the meetings when in the vicinity, and, if located in this District for any length of time, their membership in the Association will be appreciated.

(Abstract of Minutes of Meeting)

January 12th, 1920.—The meeting was called to order by L. M. Grant, President; G. A. Collins, Secretary; and present, also, 20 members and guests.

The report of the Secretary on sending Mr. J. C. Ralston to Washington to work for the Board of Public Works was discussed, more especially in respect to making good the $100 pledge toward his expenses. On motion by Mr. Jos. Jacobs, duly seconded and passed unanimously, this matter was referred to the Joint Council of Associated Engineers of Seattle to raise from all engineers and contractors as much money as possible for this work, of which at least $125 should be sent to Spokane. The matter was referred to Mr. Amos Slater, Chairman of the Joint Council, who was present.

Mr. Jacobs made a further motion that all members of the Joint Council be instructed to consider this matter and work out a plan for giving active support through the other public bodies of the city to the National Board of Public Works, which was duly seconded and passed unanimously. Mr. J. L. Hall moved that the meeting go on record as favoring the Jones-Reavis Bill, and to advise the delegates to Congress accordingly. The motion was duly seconded and passed unanimously. The President appointed Mr. Jacobs and Mr. Dimock a Committee to arrange the underwriting of $125 00 to be advanced to Spokane on account of Mr. Ralston's expenses.

Mr. Hall opened the discussion on the Development Committee report. Mr. Jacobs commented in favor of its adoption in principle. The same point of view was expressed by Messrs. Dimock, Hall, Collins and others present. Mr. Chauncy Wernecke moved that the meeting approve the principles laid down in Divisions A, B and D, which motion was carried unanimously. Mr. A. H. Dimock moved the approval of the principle laid down in Division C, which was passed with one dissenting vote.

Mr. Jacobs then moved that the *Engineering News-Record* be informed by telegraph of the action in favor of the report of the Development Committee. Motion passed unanimously.

Adjourned.

Southern California Association, Organized 1914.

W. K. Barnard, President; Floyd G. Dessery, Secretary, 514 Central Building, Los Angeles, Cal.

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular monthly meetings on the second Wednesday of each month, the December meeting being the Annual Meeting.

Informal luncheons in connection with the Joint Technical Societies of Los Angeles are held at 12.15 P. M., every Thursday at the Broadway Department Store Café.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

(Abstract of Minutes of Meeting)

January 8th, 1920.—The meeting was called to order at the Jonathan Club; President W. K. Barnard in the chair; Floyd G. Dessery, Secretary; and present, also, 30 members and 15 guests. This meeting followed a dinner at which President Barnard introduced various guests of the Association, and Mr. Chas. S. Burnell, the City Attorney, explained in detail the new City Business Tax Ordinance.

Minutes of the Annual Meeting were approved without reading.

A Committee consisting of Messrs. Reed, Wheeler and Bowen presented a resolution of sympathy and condolence with Mr. E. L. Adams in the sudden death by accident of his father, Mr. George C. Adams, which was duly seconded and carried.

Following a communication from C. H. Lee, State Water Commissioner, advising of the curtailment of funds available for the work of the U. S. Geological Survey in California, it was duly moved, seconded, and carried after considerable discussion, that vigorous action be taken to continue the work of the Survey uninterruptedly in California.

Mr. H. W. Dennis, Chairman of the Committee on Ways and Means—1920 Convention, reported that to date 42 members of the Association had underwritten and guaranteed $2 220.

After thorough discussion, it was moved, seconded and carried that it was the sense of the meeting that the resolution adopted at the meeting of December 10th, 1919, instructing Director H. Hawgood to bring the 1920 Convention of the Society to Los Angeles be indorsed, and Director Hawgood so advised.

Maj. Chas. T. Leeds presented a paper entitled "Channel Improvement as a Factor in Flood Control."

A resolution presented as coming from the City Planning Association was debated and finally laid on the table. A Committee of five was authorized by the meeting to handle all matters on City Planning, and the President appointed Messrs. Lippincott, Hawgood, Storrow, Sonderegger, and W. D. Smith.

Mr. Howell referred to the proposed National Board of Public Works and the appeal for funds to support that movement.

Adjourned.

Spokane Association, Organized 1914.

Alfred D. Butler, President; Charles E. Davis, Secretary-Treasurer, 401 City Hall, Spokane, Wash.

The regular meetings of the Association are held on the second Friday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Visiting members are invited to attend the meetings.

Texas Association, Organized 1913.

Hans Helland, President; E. N. Noyes, Secretary, Dure Building, Dallas, Tex.

Utah Association, Organized 1916.

A. B. Villadsen, President, 304 Dooly Bldg., Salt Lake City, Utah.
The Annual Meeting of the Association is held on the first Wednesday in April. The time of other meetings is not fixed, but this information will be furnished on application to the President.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcome in the Reading Rooms and at the meetings of many engineering societies in all parts of the world. A list of such socicties will be found on pages 41 and 42 of the Year Book of the Society for 1919.

NEW BOOKS*

(From January 1st to January 31st, 1920)

The statements made in these notices are taken from the books themselves, and this Society is not responsible for them.

DONATIONS TO ENGINEERING SOCIETIES LIBRARY

APPLIED CALCULUS.

Principles and Applications. Essentials for Students and Engineers. By Robert Gibbes Thomas. 1919. N. Y., D. Van Nostrand Company. 490 pp., 45 exercises, 166 figures, 5 x 7 in., cloth. $3.00.

In this college text-book, the author has aimed to make clear the basic principles of the calculus and to show that fundamental ideas are involved in familiar problems. Effort has been directed toward the attainment of a working and fruitful knowledge of the elements of the subject and an ability to use it efficiently.

ATLAS AMERICA LATINA.

1919. General Drafting Company, Inc., New York. 196 pp., cloth, 11 x 16 in. $20.

The detailed maps which form the most important part of this atlas have been prepared from the best authorities. They cover Mexico, Central and South America and the West Indies and are drawn to a uniform scale of fifty miles to the inch. Towns, railways, administrative divisions and physical features are clearly shown and a geographic index is provided.

The atlas also contains general maps showing steamship routes, ocean currents, natural vegetation, prevailing winds, summer and winter rainfall and temperatures, principal products, principal minerals and the language divisions of Latin America, as well as charts showing the foreign trade of each country and descriptive articles concerning their possibilities and conditions.

AVIATION. THEORICO-PRACTICAL TEXT-BOOK FOR STUDENTS.

By Benjamin M. Carmina. N. Y., The Macmillan Co. 1919. 172 pp., 92 diagrams, table, 8 x 5 in., cloth. $2.

The author discusses the theory of flight and the construction, rigging and maintenance of airplanes, and gives suggestions on flying. The treatment is non-mathematical throughout, but an appendix is included which gives the mathematical analysis of the laws governing flight.

DER BAU DES DIESELMOTORS.

By Kamillo Körner. Berlin, Julius Springer. 1918. 350 pp. 500 diagrams, 11 x 7 in., cloth. 30 marks.

The present work is devoted to the practical details of Diesel engine construction and omits all discussion of theoretical considerations. The various elements of engines are discussed in detail and examples of the usual designs are given.

CHILTON TRACTOR INDEX, VOL. 3, No. 1. JANUARY, 1920.

Philadelphia, Chilton Company. 478 pp., 10 x 7 in., paper. $1.00.

The Tractor Index is a directory of the farm tractor industry of the country, which gives in tabulated form the specifications of the tractors on the market, lists of tractor and power farm machinery manufacturers, makers of parts and accessories and farm trucks. In addition to these directories, the volume includes a collection of data and articles on power farming, farm lighting plants, tractor testing, tractor standards and other topics of interest to users and dealers.

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* Unless otherwise specified, books in this list have been donated by the publishers.

CONTROLLERS FOR ELECTRIC MOTORS.

A Treatise on the Modern Industrial Controller, Together With Typical Applications to the Industries. By Henry Duvall James. N. Y., D. Van Nostrand Company. 1919. 354 pp. 43 pp. 259 illus., cloth, 8 x 5 in. $3.00.

The aim of this volume, which is based on a series of articles published in the *Electric Journal* during 1917 and 1918, is to provide students, operating engineers and users of electrical apparatus, with a good general account of industrial controllers and an explanation of their principles of operation.

THE ELEMENTS OF ASTRONOMY FOR SURVEYORS.

By R. W. Chapman. 1919. Lond., Charles Griffin and Co., Ltd.; Phila., J. B. Lippincott Company. 247 pp., 56 diagrams, 5 x 7 in., cloth. $1.75.

Although there are several excellent books on surveying that deal more or less thoroughly with astronomical observations, the author of this work believes that there is a need for an elementary work suitable for the student and for the surveyor who is taking up astronomical observation for the first time. The present work is an attempt to provide an elementary exposition, not only of the practical methods of observation and computation, but also of the main principles that must be thoroughly understood if the surveyor is to be master of his profession.

GOVERNORS AND THE GOVERNING OF PRIME MOVERS.

By W. Trinks. N. Y., D. Van Nostrand Co., 1919. 236 pp. + 28 pp., 140 illus., 6 x 9 in., cloth. $3.50.

This volume aims to present the principles and essentials of the subject in such a manner that the reader may be able to judge existing and future types of governors as well as the properties of prime movers with regard to regulation. It has been written to provide a text-book on the general subject of governors and governing, upon which, the author states, there is no book of any consequence in English. A selected bibliography is included.

THE GREAT LAKES RED BOOK.

A List of Over 1 000 Vessels of the Great Lakes, With the Name of Owner, Captain and Engineer of Each Vessel. Cleveland, The Marine Review, 1919. 159 pp., 5 x 3 in., paper. $1.00.

Gives a list of the fleets upon the Great Lakes as well as owners, captains and engineers. There is also a table showing capacity of ore-carriers and a port directory.

MINING MATHEMATICS SIMPLIFIED.

By James Wardlaw, Sr., Scottdale, Pa. 1919. 189 pp., 7 x 5 in., cloth. $2.50.

This volume gives simple arithmetical solutions for the problems which confront the practical miner. The author is engaged in preparing miners for examinations for certificates as fire bosses, foremen, etc. in the Pennsylvania bituminous coal-field and has written this text for their use.

THE NEW AMERICAN THRIFT.

The Annals of the American Academy of Political and Social Science. Vol. 87, No. 176, January, 1920. Philadelphia, Pa. 248 pp., paper. $1.00.

Contents: Introduction.—Thrift for the individual and the family.—Thrift for the nation.—American needs for capital; typical examples.—Thrift in resources and industry; typical examples.—The investment of savings.—The promotion and practice of thrift in different countries.—Suggestions for promoting thrift.

A symposium by a number of bankers, economists and business men on the desirability of thrift in national and individual life. The problem is broadly presented and discussed in its various phases by experts.

ORGANIZING FOR WORK.

By H. L. Gantt. 1919. N. Y., Harcourt, Brace & Howe. 113 pp., cloth, 7 x 5 in. $1.25.

Our civilization depends, according to Mr. Gantt, upon the effectiveness with which our combined industrial and business system work, and recent revolutionary attempts to overthrow it are due to the failure of the present system to recognize fully its responsibility to the community. The author believes that there must be a return to the principle that the first aim of business is to render service to the community and that this result can be peacefully obtained by the use of familiar methods, whose use for the purpose he discusses in the present book.

THE PRINCIPLES OF ELECTRICAL ENGINEERING AND THEIR APPLICATION. VOL. 2. APPLICATION.

By Gisbert Kapp. N. Y., Longmans, Green & Co.; Lond., Edward Arnold. 1919. 388 pp., 6 x 9 in., cloth, 173 diag. $6.00.

The present textbook is intended for all engineering students and also as a handbook for general engineers. For the latter, the author attempts to provide a work which will give him the fundamental principles of the subject and describe their application in practical engineering, without burdening him with minute details of design. It will, the author hopes, enable the general engineer to determine whether and how any particular piece of electrical plant can be used or adapted for a particular purpose.

Volume 1, dealing with Principles, appeared in 1916. The present volume treats of the applications of these principles in electrical machines.

PRINCIPLES OF METALLOGRAPHY.

By Robert S. Williams. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd. 1920. 158 pp., 75 illus., tables, 8 x 5 in., cloth. $2.00.

This is a brief introduction to the subject written for students of general science or engineering, who do not specialize in metallography but who will use it to a limited extent in connection with their professional work, and for general readers who wish an introduction to more specialized books. Particular attention is given to the applications of metallography.

RADIO ENGINEERING PRINCIPLES.

By Henri Lauer and Harry L. Brown. 1st edition. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1920. 300 pp., 241 diag., 6 x 9 in., cloth. $3.50.

This is a general textbook on radio, written to present the extensive developments in the art made during the war. It consequently is largely devoted to the study of the characteristics and use of the three-electrode vacuum tube in radiotelegraphy and radiotelephony. Sufficient attention has, however, been given to the principles involved in older apparatus to meet the requirements of a general textbook.

THE RAILROAD PROBLEM.

The Annals of The American Academy of Political and Social Science. Vol. 86, No. 175. November, 1919. Philadelphia. Paper, 6 x 10 in., 252 pp. $1.00.

In this collection of articles by various economists, financiers and railroad men, emphasis has been placed on the current issues as to railroad regulation and the participation of labor in railroad management. The major topics discussed are government operation, current proposals for regulation, the unification of terminals and railway efficiency and labor.

SELENIUM CELLS AND HOW THEY ARE MADE.

Compiled and arranged by Samuel Wein. 1919. N. Y., The Progress Publishing Company. 33 pp., illus., paper, 8 x 6 in. $1.00.

This pamphlet presents a concise chronological review of the development of the selenium cell. The various types of selenium cells are described, briefly but explicitly, and diagrammatic illustrations of the more important ones are given. The descriptions have been prepared after an examination of the available literature.

SOUTHERN PINE MANUAL.

Standard Wood Construction. 1919. New Orleans, La., Southern Pine Association. 136 pp. + 10 pp., diagrams and tables, 4 x 6 in., cloth. $1.00.

This small volume is an engineering handbook for engineers, architects and builders. Tables are given showing the dimensions and properties of yellow pine beams and columns and joists, the specifications of various engineering societies, the permitted working stresses adopted by various cities, and miscellaneous tables of use to users of wood in construction.

THE STORY OF ELECTRICITY. VOL. 1.

Edited by T. Commerford Martin and Stephen Leidy Coles. 1919. N. Y., The Story of Electricity Company. 661 pp., 11 x 8 in., cloth. $25 for Vols. 1 and 2.

The authors of this volume have prepared an account in popular language of the development of the electrical industry, with particular reference to American achievement. After an introductory chapter on the beginnings of electrical science, the invention and growth of the telegraph, telephone, central station, electric railway, etc. are described. Chapters are devoted to the great electrical companies. The various chapters are accompanied by biographical sketches and portraits of engineers of prominence, past and present. Numerous well-selected illustrations add to the value of the work.

A TEXT-BOOK OF RAND METALLURGICAL PRACTICE. VOL. 2.

By Ralph Stokes, Jas. E. Thomas, G. O. Smart, W. R. Dowling, H. A. White, E. H. Johnson, W. A. Caldecott, A. McA. Johnston and C. O. Schmitt. 2nd edition, revised. 1919. Lond., Charles Griffin & Company, Ltd., 462 pp., 467 illus., cloth, 9 x 6 in. 25 shillings.

This work was prepared in 1911 by a body of technical men actively engaged in current metallurgical practice upon the Witwatersrand, to provide a textbook giving a detailed account of the methods in actual use in that district, both mechanical and chemical.

The present volume, which discusses the design and construction of reduction plants and the transport of materials is by C. O. Schmitt. No radical change in practice has occurred since the publication of the previous edition, but considerable progress in the development of the use of heavy stamps aud tube mills, and a corresponding advance in the methods of classification and amalgamation have been made. This revised edition has been prepared in the light of these improvements.

TEXT-BOOK OF WIRELESS TELEGRAPHY. VOLS. 1 AND 2.

Vol. 1. General Theory and Practice. Vol. 2. Valves and Valve Apparatus. By Rupert Stanley. New edition in 2 vols. 1919. Lond., N. Y., Longmans, Green & Company. Vol. 1, 470 pp.; Vol. 2, 357 pp., 9 x 6 in., cloth. $10.00.

In the preparation of this textbook for the instruction of wireless operators, the author has kept in mind the special needs of those who have had little preliminary knowledge of electrical matters. He has therefore provided the instruction in elementary electricity and magnetism necessary for an understanding of the principles of energy radiation.

Calculations and formulas have been made as simple as possible in the technical portion of the book and the descriptions of apparatus have been restricted to the best modern types.

The present edition has been largely rewritten and rearranged. Much new matter has been included and a second volume, devoted to valves and valve apparatus, has been added.

MEMBERSHIP

(From January 9th, 1919, to February 6th, 1920)

ADDITIONS

MEMBERS

		Date of Membership.
ARN, WILLIAM GODFREY. Asst. Engr., M. of W., Ill. Cent. R. R. and Yazoo & Mississippi Val. R. R., 706 Ill. Cent. Station, Chicago, Ill.	Jun. Assoc. M. M.	Oct. 2, 1900 April 6, 1909 Jan. 20, 1920
BALCOMB, JOHN CAPRON. Vice-Pres. and Chf. Engr., Fenlack Constr. Co., Boston Rd. and Baychester Ave., New York City		Jan. 19, 1920
BLACKWELL, PAUL ALEXANDER. Asst. Chf. Engr., Virginia Bridge & Iron Co., Box 771, Roanoke, Va.	Jun. Assoc. M. M.	Dec. 4, 1900 Jan. 3, 1906 Jan. 20, 1920
BUCK, EDWARD CLARKE. Care, Colonial Office, Downing St., London, S. W., England		Oct. 14, 1919
CAREY, EDWARD GILMAN. Engr., Nitrates Div. War Dept.; Res., Hinsdale, N. H.	Assoc. M. M.	July 1, 1909 Jan. 20, 1920
CHAPMAN, ARNOLD GOODWIN. Cons. Engr., 100 State St. (Res., 154 Chestnut St.), Albany, N. Y.	Jun. Assoc. M. M.	July 1, 1909 April 30, 1912 Jan. 20, 1920
CLEARY, ALFRED JOHN. Chf. Asst. City Engr., City Hall, San Francisco, Cal.	Assoc. M. M.	Sept. 3, 1913 Nov. 25, 1919
EATON, JAMES HAWORTH. 36 Islington Rd., Auburndale, Mass.		Jan. 19, 1920
GORIACHKOVSKY, VLADIMIR. Care, Youroveta Home & Foreign Trade Co., Inc., 165 Broadway, New York City		Nov 25, 1919
HEWES, LAURENCE ILSEY. Gen. Insp., Bureau Public Roads, Three Western Districts, Post Office Bldg., Portland, Ore.		Oct. 14, 1919
HOGG, THOMAS HENRY. Asst. Hydr. Engr., Hydro-Elec. Power Comm. of Ontario, 117 Normandy Boulevard, Toronto, Ont., Canada		Nov. 25, 1919
KNIGHT, SEYMOUR H. Advisory Engr., Day & Zimmermann, Inc., 611 Chestnut St., Philadelphia, Pa.		Jan. 19, 1920
LANCASTER, WILLIAM LOUIS. Care, Highway Service, North Carolina, Box 811, Greensboro, N. C.		Sept. 9, 1919
LATIMER, ROBERT CATHCART. Chf. Engr., Ambursen Constr. Co., 61 Broadway, New York City		Jan. 19, 1920
LAURSON, PHILIP GUSTAVE. Asst. Prof. Eng. Mechanics, Sheffield Scientific School, Yale Univ. (Res., 1345 Chapel St.), New Haven, Conn.		Jan. 19, 1920
MACMILLAN, JOHN. (Sumner & MacMillan), 318 H. W. Hellman Bldg., Los Angeles, Cal.		Nov. 25, 1919
MATTESON, BYRON WYNNE. Engr., Modena-St. George Post Road Project, 403 Col. Hudson Bldg., Ogden, Utah		Jan. 19, 1920

MEMBERS (*Continued*)		Date of Membership.
Morris, Thomas Carlyle. Special Asst. Engr., Panama Canal, Balboa Heights, Canal Zone, Panama		Nov. 25, 1919
Pease, James Norman. Superv. Engr., Lockwood-Greene & Co., 1530 Healey Bldg., Atlanta, Ga		Nov. 25, 1919
Reed, John. Senior Roadway Engr., Federal Valuation of Railroads, Interstate Commerce Comm., Bureau of Valuation, The Kenesaw, 16th and Irving Sts., Washington, D. C		Jan. 19, 1920
Sanborn, James Forrest. Cons. Engr., 35 West 39th St., New York City	Assoc. M. M.	May 4, 1904 Jan. 20, 1920
Soest, Hugo Conrad. Asst. Engr., I. R. T. Co., 50 Park Pl., New York City	Jun. Assoc. M. M.	May 31, 1910 Sept. 2, 1914 Jan. 20, 1920
Steep, James Bigelow. Asst. Gen. Mgr., Citizens Gas Co., 205 Majestic Bldg., Indianapolis, Ind	Assoc. M. M.	Feb. 4, 1913 Jan. 20, 1920
Stimson, Earl. Gen. Supt., M. of W., B. & O. R. R., B. & O. Bldg., Baltimore, Md		Jan. 19, 1920
Vogdes, Joseph Johnson. Engr., Brann & Stuart Co., Inc., Commercial Trust Bldg., Philadelphia, Pa	Assoc. M. M.	Oct. 9, 1917 Jan. 20, 1920
Whitson, Milton James. Care, Stone & Webster, 120 Broadway, New York City		Oct. 14, 1919
Widmer, Arthur Jacob. Pres., Widmer Eng. Co., 1636 Syndicate Trust Bldg., St. Louis (Res., 212 South Elm Ave., Webster Groves), Mo		Jan. 19, 1920
ASSOCIATE MEMBERS		
Ayres, Quincy Claude. Asst. Prof., Civ. Eng., Univ. of Mississippi, Box 341, Oxford, Miss	Jun. Assoc. M.	Feb. 4, 1914 Jan. 19, 1920
Bird, Matthew McClung. Care, State Highway Dept., Nashville, Tenn		Jan. 19, 1920
Bishop, Roy Prentice. Gen. Mgr., The Carolina Eng. Co., Wilmington, N. C	Jun. Assoc. M.	June 23, 1916 Jan. 19, 1920
Bowman, Hubert Dickson. 1604 University Ave., New York City		Nov. 25, 1919
Brown, Morris. Asst. Engr., McClintic Marshall Steel Supply Co., Box 112, East Liberty P. O., Pittsburgh, Pa		Jan. 19, 1920
Cameron, Edward Hugh. 42 Linden St., New London, Conn		Jan. 19, 1920
Cassel, Charles Cadwallader. Acting Div. Engr., Div. 3, New York State Highway Comm., 538 Franklin St., Watertown, N. Y		Oct. 14, 1919

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
CAYE, WILLIAM CASSIUS, JR. Div. Engr., Highway Dept. of Georgia, Box 34, Americus, Ga.		Jan. 19, 1920
COLCORD, FRANCIS CARLTON. Gen. Mgr., Colcord Coal Co., Montcoal, W. Va.		Jan. 19, 1920
COOMBS, DONALD GLADSTONE. Office Engr., Const. Dept., Braden Copper Co., Caletones, Rancagua, Chile	Jun. Assoc. M.	Sept. 12, 1916 Oct. 14, 1919
CROZIER, BERNARD LABROQUERE. Asst. Engr., Paving Comm., City of Baltimore, 2721 St. Paul St., Baltimore, Md.		Jan. 19, 1920
DAINO, ANTHONY JOSEPH. Secy., Slattery Eng. & Constr. Co., Inc., 317 West 80th St., New York City		Jan. 19, 1920
DOANE, RALPH AVARD. Asst. Engr., Eng. Dept., Town of Brookline, 1376 Commonwealth Ave., Boston, Mass.		Sept. 9, 1919
FARRELL, JAMES PATRICK. Dist. Supt., Philadelphia Dist., The Austin Co., 1026 Bulletin Bldg., Philadelphia, Pa.		Jan. 19, 1920
FINCK, GEORGE EDWARD. Asst. Engr., Paving Comm., City of Baltimore, 1932 East 31st St., Baltimore, Md.		Jan. 19, 1920
GEORGE, ABRAM NUTE. Res. Engr., California Highway Comm., 2832 Imperial Ave., San Diego, Cal.		Jan. 19, 1920
GRAFFIN, EDWARD DAVID. Lieut. (Junior Grade), C. E. C. U. S. N. Asst. Civ. Engr., Bureau of Yards and Docks, Navy Dept., 4014 Washington Ave., Newport News, Va.		Jan. 19, 1920
HAEFNER, CARL WILLIAM. 117 South 1st Ave., Mount Vernon, N. Y.		Sept. 9, 1919
HAMMEL, EDWARD FREDERIC. Editor, Dept. of Architectural Eng. The Am. Architect 243 West 39th St., New York City	Jun. M.	Feb. 1, 1910 Nov. 25, 1919
HARGIS, ANDREW BROADUS. 1200 Jones Bldg., Pittsburgh, Pa.		Sept. 9, 1919
HAWLEY, JOHN CHURCH. Engr., Firemen's Mutual Insurance Co., 841 David Whitney Bldg., Detroit, Mich.		Jan. 19, 1920
HEALEY, FRANK FIFIELD. Asst. to Pres., The C. F. Pease Co., 213 Institute Pl., Chicago, Ill.		Jan. 19, 1920
HOGAN, FRANCIS VINCENT. Secy.-Treas., Panzieri-Hogan Co., 90 State St., Albany, N. Y.		Oct. 14, 1919
HOPPER, CLARENCE RICKER. 97 Quitman St., Newark, N. J.		Jan. 19, 1920
JAMES, REGINALD HEBER. Insp. and Asst. Engr., Dept. of Wharves, Docks and Ferries, 4110 Manayunk Ave., Roxborough, Philadelphia, Pa.		Jan. 19, 1920
JOHNSON, FRANK ARTHUR. Prin. Asst. Engr., H. J. Brunnier, 1946 El Dorado Ave., Berkeley, Cal.		Nov. 25, 1919
KLINE, WILMER ZIEGENFUSS. Structural Steel Draftsman, Public Works Dept., Philadelphia Navy Yard, 240 Somerville Ave., Philadelphia, Pa.		Jan. 19, 1920

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
KNIGHT, ALEXANDER CLINTON. Maj., Corps of Engrs., U. S. A., 2200 Linden Ave., Baltimore, Md.		Nov. 25, 1919
KOESTER, EDWIN FERDINAND. Engr. in Chg., Surveying Dept., Street and Sewer Dept., City of Wilmington, 811 West St., Wilmington, Del.	Jun. Assoc. M.	Oct. 8, 1918 Jan. 19, 1920
KRANZ, HENRY HUGO. 1215 Casey St., Dallas, Tex.		Nov. 25, 1919
LANZENDORF, OSCAR WILLIAM. Asst. County Engr., Sutter County, Box 36, Yuba City, Cal.		Jan. 19, 1920
LILLY, WALTER HARRISON. Bridge Engr., Hunt Eng. Co., 515 Reliance Bldg., Kansas City, Mo.		Jan. 19, 1920
LUNDAHL, RAYMOND RUDOLPH. Div. Engr., Sewerage Comm., City of Milwaukee, 347½ Twenty-fourth St., Milwaukee, Wis.		Jan. 19, 1920
MCGEHEARTY, JEROME FRANCIS JOSEPH. Head Draftsman, Supervision and Inspection of Constr., Efficiency Engr., Swift & Co., 1617 May St., Fort Worth, Tex.		Nov. 25, 1919
MANNING, WILLIAM JAMES HENRY. Asst. Engr., The Delaware & Hudson Co. (Res., 762 Madison Ave.), Albany, N. Y.	Jun. Assoc. M.	Feb. 4, 1914 Jan. 19, 1920
MARSDEN, RAYMOND ROBB. Prof., Civ. Eng., Thayer School, Dartmouth Coll., Hanover, N. H.		Jan. 19, 1920
MILLER, PERRY KAY. 87 Midland Ave., Montclair, N. J.		Jan. 19, 1920
NAGLE, JOHN MARION. Highway Engr. (Cock & Nagle), Seymour, Tex.		Jan. 19, 1920
NORRIS, WILLIAM JAMES. Care, The Whitney Co., Bay City, Ore.		Nov. 25, 1919
NORTH, ALFRED CHANDLER. Min. Engr., Box 146, Auburn, Cal.		Sept. 9, 1919
PFLANZ, ERNEST LEOPOLD. Div. Engr., Sewerage Comm., Milwaukee, 223 Oneida St., Milwaukee, Wis.		Jan. 19, 1920
PROVAZNIK, WILLIAM JOSEPH. Asst. Engr. in Chg. of Sewers, City Engr.'s Office, Omaha, Nebr.		Sept. 9, 1919
QUATTLEBAUM, SELBY. Supt., Highway Erection, Virginia Bridge & Iron Co., Box 316, Roanoke, Va.		Jan. 19, 1920
RADER, RALPH DENNIS. 217 East Jackson Ave., Jonesboro, Ark.		Jan. 19, 1920
ROBERTS, HAROLD WHITNEY. Res. Engr., Turner Constr. Co., 422 Mason Bldg., Houston, Tex.	Jun. Assoc. M.	Oct. 5, 1909 Jan. 19, 1920
ROED, OLAF ANDREW. Chf. Bridge Engr., St. Louis County, Room 212, Court House, Duluth, Minn.		Jan. 19, 1920
SAUNDERS, ROBERT SPEIRS. Junior Engr., Public Service Comm., First Dist., 414 First St., College Point, N. Y.		Jan. 19, 1920
SCHOYEN, AXEL SOPHUS. Designing Engr., Gunvald Aus Co., Interhaven Ave., Plainfield, N. J.		Jan. 19, 1920

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
SHAW, SILAS FREDERICK. Supt. of Mines, Am. Smelting & Refining Co., Charcas, S. L. P., Mexico		Jan. 19, 1920
SIMON, FRED LESTER. 24 Commerce St., Baltimore, Md.		Jan. 19, 1920
SMITH, JAMES AXTELL. 2 East 10th St., Brooklyn, N. Y.		Sept. 9, 1919
STIVER, CHRISTIAN ERLE. 124 South Pacific St., Cape Girardeau, Mo.		Jan. 19, 1920
TILGHMAN, HARRISON. Capt., C. A. C., U. S. A.; Care, Col. Oswald Tilghman, Easton, Md.		Jan. 19, 1920
TREAT, GUY BRADFORD. Chf. Engr. and Asst. Mgr., Oklahoma Ry., 213 Terminal Bldg., Oklahoma, Okla.		Jan. 19, 1920
WHIPPLE, STEPHEN CARSON. Asst. Engr., State Water Comm., 632 New Call Bldg., San Francisco, Cal.		Jan. 19, 1920
WHITNEY, JOHN THAD. State Engr. Office, Box 259, Montpelier (Res., 82 Main St., Northfield), Vt.	Jun. Assoc. M.	April 1, 1914 Jan. 19, 1920
WILLIAMS, SIDNEY JAMES. Secy. and Chf. Engr., National Safety Council, 168 North Michigan Ave., Chicago, Ill.		Jan. 19, 1920
YOUNG, GEORGE RICHMOND. 501 Marshall St., Apartment 23, Milwaukee, Wis.		Jan. 19, 1920

JUNIORS

COON, MORTIMER FREMONT. Estimator, Steel Plate Constr., Petroleum Iron Works, 144 Logan Ave., Sharon, Pa.	Jan. 19, 1920
DOYNE, MAX HARRY. Prin. Asst. Engr., C. E. Smith, 2073 Ry. Exchange Bldg., St. Louis, Mo.	Jan. 19, 1920
HARVEY, ALDEN WALES. 168 West 96th St., New York City.	June 11, 1917
HENNING, CASPAR FERDINAND. Res. Eng., Alvord & Burdick, Hartford Bldg., Chicago, Ill.	Jan. 19, 1920
HUNTLEY, NELSON HARTWELL. Draftsman, Pittsburgh-Des Moines Steel Co., 51 Coulter St., Pittsburgh, Pa.	Jan. 19, 1920
PFEIFFER, FREDERIC BARRINGER. Care, U. S. Lock, R. F. D. No. 3, Berkley, Va.	Nov. 25, 1919
PONSFORD, HENRY JORDAN. Gen. Contr. (H. T. Ponsford & Sons), 2921 Wheeling St., El Paso, Tex.	Jan. 19, 1920
STEVENSON, EBERLE UPSHAW. Draftsman and Instrumentman, Carter & Knoch, 1722 Park Ave., Little Rock, Ark.	Jan. 19, 1920
VARNEY, EDWARD ALLEN. Office of Prin., Wentworth Inst., Huntington Ave. and Ruggles St., Boston, Mass.	Nov. 25, 1919
ZEE, NAI-ZUNG. 331 Peking Rd., Shanghai, China	Oct. 14, 1919

REINSTATEMENTS	Date of Reinstatement.
BATCHELDER, BENJAMIN FRANKLIN	Jan. 20, 1920
PERKINS, PHILO SACKETT	Jan. 20, 1920

RESIGNATIONS

MEMBERS

	Date of Resignation.
Graham, Charles Hallett	Dec. 31, 1919
Hess, Alfred Elmer	Dec. 31, 1919
Musson, Eugene Francis	Dec. 31, 1919
Tittmann, Otto Hilgard	Dec. 31, 1919
Watt, David Alexander	Dec. 31, 1919
Wright, Charles Herbert	Dec. 31, 1919

ASSOCIATE MEMBERS

Baine, George Fredson	Dec. 31, 1919
Beck, Ralph Ernest	Dec. 31, 1919
Burns, Walter Elliott	Dec. 31, 1919
Christensen, George Andrew	Dec. 31, 1919
David, Fred Carnot	Dec. 31, 1919
Edwards, Frederick	Dec. 31, 1919
Ellis, Guernsey William	Dec. 31, 1919
Fenkell, Neal Charles	Dec. 31, 1919
Goldsmith, Nathaniel Oliver	Dec. 31, 1919
Haas, Philip Lippman	Dec. 31, 1919
Hill, William Andrew	Dec. 31, 1919
Keith, Lorin Acil	Dec. 31, 1919
Peterson, John Ferdinand	Dec. 31, 1919
Sachse, Richard	Dec. 31, 1919
Scott, John Kuhn	Dec. 31, 1919
Shema, Joseph	Dec. 31, 1919
Strong, Arthur Leon	Dec. 31, 1919

JUNIORS

DaLee, William Amon	Dec. 31, 1919
Greene, Robert Nesbitt	Dec. 31, 1919
Gross, Frederick Henry	Dec. 31, 1919

DEATHS

Browne, William Lyon. Elected Member January 31st, 1911; died November 24th, 1919.

Christophers, Reginald Gillon. Elected Associate Member, June 24th, 1914; died October 13th, 1918.

Lehnartz, Frederick William. Elected Member, August 6th 1879; died February 14th, 1919.

Weston, George. Elected Member, June 5th, 1907; died January 7th, 1920.

Total Membership of the Society, February 6th, 1920.

9 467.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(December 22d, 1919, to February 1st, 1920)

NOTE.—*This list is published for the purpose of placing before the members of this Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Journal,* Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Journal,* Eng. Inst. of Canada, Montreal, Que., Canada.
(6) *Journal,* Am. Inst. of Archts., Washington, D. C., 50c.
(7) *Gesundheits Ingenieur,* Munich, Germany.
(8) *Stevens Indicator,* Hoboken, N. J., 50c.
(9) *Industrial Management,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News-Record,* New York City, 15c.
(15) *Railway Age,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Electric Railway Journal,* New York City, 10c.
(18) *Railway Review,* Chicago, Ill., 15c.
(19) *Scientific American Supplement,* New York City, 10c.
(20) *Iron Age,* New York City, 20c.
(21) *Railway Engineer,* London, England, 1s. 2d.
(22) *Iron and Coal Trades Review,* London, England, 6d.
(24) *American Gas Engineering Journal,* New York City, 10c.
(25) *Railway Mechanical Engineer,* New York City, 20c.
(26) *Electrical Review,* London, England, 4d.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Royal Soc. of Arts, London, England, 6d.
(32) *Mémoires et Compte Rendu des Travaux,* Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil,* Paris, France, 1 fr.
(36) *Cornell Civil Engineer,* Ithaca, N. Y.
(40) *Zentralblatt der Bauverwaltung,* Berlin, Germany, 60 pfg.
(41) *Elektrotechnische Zeitschrift,* Berlin, Germany.
(42) *Proceedings,* Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées,* Paris, France.
(45) *Coal Age,* New York City, 15c.
(46) *Scientific American,* New York City, 15c.
(47) *Mechanical Engineer,* Manchester, England, 3d.
(48) *Zeitschrift,* Verein Deutscher Ingenieure, Berlin, Germany, 1, 60 m.
(49) *Zeitschrift für Bauwesen,* Berlin, Germany.
(50) *Stahl und Eisen,* Düsseldorf, Germany.
(53) *Zeitschrift,* Oesterreichischer Ingenieur und Architekten-Verein, Vienna, Austria, 70h.
(54) *Transactions,* Am. Soc. C. E., New York City, $16.
(55) *Mechanical Engineering:* Journal, Am. Soc. M. E., New York City, 35c.
(56) *Transactions,* Am. Inst. Min. and Metallurgical Engrs., New York City, $6.
(57) *Colliery Guardian,* London, England, 5d.
(58) *Proceedings,* Engrs.' Soc. of W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings,* American Water Works Assoc., Troy, N. Y.
(60) *Municipal and County Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Drop Forger,* Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 10c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Gas Journal,* London, England, 6d.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(69) *Eisenbau,* Leipzig, Germany.

* Illustrated.

(71) *Journal*, Iron and Steel Inst., London, England.
(71a) *Carnegie Scholarship Memoirs*, Iron and Steel Inst., London, England.
(72) *American Machinist*, New York City, 15c.
(73) *Electrician*, London, England, 18c.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(77) *Journal*, Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen*, Vienna, Austria, 1, 50m.
(80) *Tonindustrie Zeitung*, Berlin, Germany.
(83) *Gas Age*, New York City, 15c.
(85) *Proceedings*, Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering and Contracting*, Chicago, Ill., 10c.
(87) *Railway Maintenance Engineer*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings*, Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions*, Inst. of Naval Archts., London, England.
(91) *Transactions*, Soc. of Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin*, Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie*, Paris, France, 4 fr. 50.
(96) *Canadian Engineer*, Toronto, Ont., Canada, 10c.
(98) *Journal*, Engrs. Soc. of Pa., Harrisburg, Pa., 30c.
(99) *Proceedings*, Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs*, Corps of Engrs., U. S. A., Washington, D. C., 50c.
(103) *Mining and Scientific Press*, San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer*, London, England, 6d.
(105) *Chemical and Metallurgical Engineering*, New York City, 25c.
(106) *Transactions*, Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung*, Zürich, Switzerland.
(109) *Journal*, Boston Soc. C. E., Boston, Mass., 50c.
(111) *Journal of Electricity*, San Francisco, Cal., 25c.
(113) *Proceedings*, Am. Wood Preservers' Assoc., Baltimore, Md.
(114) *Journal*, Institution of Municipal and County Engineers, London, England, 1s. 6d.
(115) *Journal*, Engrs.' Club of St. Louis, St. Louis, Mo., 35c.
(116) *Blast Furnace and Steel Plant*, Pittsburgh, Pa., 15c.
(117) *Engineering World*, Chicago, Ill.
(118) *Times Engineering Supplement*, London, England, 2d.
(119) *Landscape Architecture*, Harrisburg, Pa., 50c.
(120) *Automotive Industries*, New York City, 15c.
(121) *Proceedings*, Am. Concrete Inst., Boston, Mass.

LIST OF ARTICLES

Bridges.

Construction of the Bear River Bridge.* A. T. Macdonald. **(5)** Oct., 1919.
A Review of Recent Advances in the Length of Spans of Different Classes of Bridges. Henry S. Jacoby. **(36)** Nov., 1919.
Highway Bridges of Steel and Concrete.* Charles D. Snead. **(60)** Dec., 1919.
The Erection of the Hell Gate Bridge.* **(21)** Dec., 1919.
An Unusual Design for a Missouri River Bridge; Wartime Conditions Enforce Use of Unique Piers Under Heavy Trusses of C., M. & St. P. Structure.* **(15)** Dec. 19, 1919.
The New 260 Ft. Span Single-Leaf Bascule Bridge of the Illinois Central R. R.* **(86)** Dec. 24, 1919.
Longest Single-Leaf Bascule Bridge: Chicago River.* **(13)** Dec. 25, 1919.
British Portable Military Bridges.* C. E. Inglis. **(86)** Dec. 31, 1919.
Bascule Bridge, Largest of Its Type, Built Over the Chicago River.* W. T. Christine. **(117)** Jan. 1.
Construction of the Canal Street Viaduct, Chicago.* P. A. Wells. **(117)** Jan. 1.
Construction of High Level Bridge at Tansley, Ont.* A. W. Connor. **(96)** Jan. 8.
High Gantry Used for Handling Heavy Members of Large Bascule.* **(13)** Jan. 8.
Unique Plant Concretes Seven-Span Arch Bridge.* Arthur Richards and Warren Carmichael. **(13)** Jan. 8.
Simple Stress Diagram for Rolling Loads.* Norman G. Kapp. **(11)** Jan. 9.
Progress in Bridge Building.* O. H. Ammann. **(117)** Jan. 15.
Long Life for Creosoted Piles in Railroad Trestle; Thirty-Five Years of Service Affords Conclusive Demonstration of the Value of Treatment.* **(15)** Jan. 16.
Pile Piers Support 300 Ft. Steel Truss Spans.* **(86)** Jan. 28.
Recent Advances in Length of Bridge Spans. Henry S. Jacoby. **(86)** Jan. 28.
Formula and Curves for Approximating Bridge Costs.* Charles D. Snead. (Abstract of paper read before the Kentucky Highway Engrs.' Convention.) **(86)** Jan. 28.
Berechnung der Biegungsmomente infolge der Eisenbahnverkehrlast für durchlaufende Träger auf drei Stützen.* Kommerell. **(49)** Serial beginning Pt. 4, 1919.

* Illustrated.

Bridges—(Continued).

Die Hängebrücke über den La Grasse-Fluss in Massena Center, N. Y.* Müllenhoff. (48) Mar. 1, 1919.
Ueber die Erhöhung der zulässigen Materialinanspruchnahme eiserner Brücken.* Friedrich Hartmann. (53) Serial beginning July 25, 1919.

Electrical.

High Potential, High Frequency Apparatus and Experiments.* F. P. Vaughan. (5) Oct., 1919.
What Is an Incandescent Lamp? R. W. Shenton. (19) Oct. 25, 1919.
Some Notes on the Installation and Maintenance of Electrical Apparatus.* W. Cross. (77) Dec., 1919.
Three-Phase Meter Testing.* A. J. Bridge. (26) Dec. 5, 1919.
Temperature Uniformity in an Electric Furnace.* John B. Ferguson. (19) Dec. 6, 1919.
The Automatic Electric Telpher and Its Use in Industrial Establishments.* N. G. Kapp. (73) Dec. 12, 1919.
Internal Actions and the Performance of Electric Furnaces.* W. K. Booth. (19) Dec. 13, 1919.
Radiant Resistor-Furnace.* F. A. J. Fitzgerald. (Paper read before the Amer. Electrochemical Soc.) (105) Dec. 17, 1919.
Magnetic Storms As Affecting Ocean Telegraph Cables.* Edward Raymond-Barker. (26) Serial beginning Dec. 19, 1919.
Self-Starting Unity-Power-Factor Synchronous Motors. F. A. Lauper. (26) Dec. 19, 1919.
Electric Furnace for Experimental Work.* F. A. J. Fitzgerald and Grant C. Moyer. (105) Dec. 24, 1919.
Renewed Lamps.* (73) Dec. 26, 1919.
A Remarkable Property of a Well-Known Alternating-Current Circuit.* E. B. Brown. (73) Dec. 26, 1919.
A System for the Reception of Continuous Waves.* John Scott-Taggart. (Paper read before Wireless Soc. of London.) (26) Dec. 26, 1919.
Semi-Automatic Induction-Generator Plants.* L. J. Moore. (27) Dec. 27, 1919.
Wireless Storm Detector for the Central Station.* Herbert T. Wade. (19) Jan.
Theory of Arc Welding.* Ralph G. Hudson. (From *Journal* of the Am. Welding Soc.) (2) Jan.
Wireless Telephony.* N. H. Slaughter. (3) Jan.
Welding Cast Iron with the Electric Arc; How to Overcome Brittleness and Cracking.* Otis Allen Kenyon. (20) Jan. 1.
Mercury Arc Rectifiers for Large Outputs.* (73) Jan. 2.
Criteria for the Testing of Magneto Magnets.* J. D. Morgan. (73) Jan. 2.
Artistic and Utilitarian Theater Lighting.* Lyman Day Morgan. (27) Jan. 3.
Requirements for Induction Motor Service.* (27) Jan. 3.
Thermal Conductivity of Underground Ducts.* Willard S. Wilder. (27) Jan. 3.
Transmission-Line Reconstruction.* P. O. Reyneau and H. P. Seelye. (27) Jan. 3.
Application of Vectors to Wiring Diagrams.* Lewis A. Tewen. (27) Jan. 10.
Reconnecting Induction Motors, Reconnecting Problems.* A. M. Dudley. (64) Jan. 13.
Arc Welding.* F. A. Anderson. (111) Jan. 15.
The A-1 Electric Spot Welders.* (22) Jan. 16.
Present-Day Practice in Relay Protection.* H. P. Woodrow. (27) Jan. 17.
Maintenance of Interior Lighting Systems.* Ward Harrison and J. R. Colville. (27) Jan. 24.
Present and Future of Line Insulators.* F. W. Peek, Jr. (27) Jan. 24.
Problems in Electric-Furnace Smelting. F. Holmgren. (105) Jan. 28; (27) Jan. 24.
Estimating Manhole Costs (Cable Manholes).* E. E. George. (13) Jan. 29.
Concrete Parts for Generators.* C. M. Hackett. (From *General Electric Review.*) (96) Jan. 29.
Les Nouvelles Installations du Tunnel du Simplon.* A. Bidault des Chaumes. (33) Serial beginning Oct. 11, 1919.
L'Etablissement par l'Etat, d'un Réseau Electrique à Haute Tension dans les Régions Libérées.* G. Tochon. (33) Nov. 15, 1919.
Kondensatoranfressungen.* (Electrical.) Milchalke. (48) Aug. 2, 1919.
Der offene Drehstrommotor in schwierigen Betrieben.* Ernst Dörffel. (48) Aug. 9, 1919.

Marine.

E. F. C. Water-Tube Boiler for Wood Ships.* F. W. Dean and Henry Kreisinger. (55) Dec., 1919.
Sequencing Material in Shipbuilding, Reduces Time and Cost of Construction.* O. E. Mills. (9) Dec., 1919.
A Test of Watertight Bulkheads for Ship Subdivision.* Archibald Hogg. (11) Dec. 5, 1919.
United States Patrol Boats of "Eagle" Class.* (11) Dec. 5, 1919.

* Illustrated.

Marine—(Continued).

The Fessenden Pelorus (Wireless Compass): A Caution as to Its Use.* R. A. Fessenden. (73) Dec. 19, 1919.
Enlarged Fleet of Ore Boats Plying Hudson; Notable Dock and Handling Equipment.* (20) Jan. 1.
The Motor Ship *Asia* for the East Asiatic Company.* (11) Jan. 2.
Structural Design of Caisson Gates for Dry Docks.* Eugene E. Halmos. (13) Jan. 8.
Oil Tank Steamer *San Fernando*.* (11) Jan. 16.
Mechanical Stokers Aboard Ship.* Charles H. Bromley. (64) Jan. 20.
Largest Derrick Built to Erect Great Hammerhead Crane, Handles 40 Tons at 125-Ft. Reach of 252-Ft. Boom in Building 350-Ton Fitting-out Crane at Philadelphia Navy Yard.* (13) Jan. 22.
Les Propriétés du Béton Armé Employé dans les Constructions Navales.* Poncet. (33) Sept. 20, 1919
Les Chalands en Béton Armé, Système. Henry Lossier.* Ch. Dantin. (33) Oct. 4, 1919.
La Commande Electrique des Vannes et des Portes de l'Ecluse à Sas du Bassin à Flot du Port de Boulogne.* A. Foillard. (33) Oct. 11, 1919.
Grue Flottante de 250 Tonnes de l'Amirauté britannique.* (33) Oct. 25, 1919.
Tracteur Automobile, Système Schneider; pour le Halage des Bateaux.* (33) Nov. 1, 1919.
Die technischen und wirtschaftlichen Grundlagen der Verwendung von Eisenbeton als Schiffbaumaterial.* Carl Commentz. (48) Serial beginning Mar. 8, 1919.
Der neue 250t-Hammerwippkran der Werft von Blohm & Voss in Hamburg.* (48) April 19, 1919.
Ueber die Beziehungen zwischen der Reaktionsstrahl-Theorie und den Flügelblatt-Theorie bei der Schiffschraube.* W. Riehn. (48) Apr. 26, 1919.
Die Holzkonservierung im Schiffbau. Ernst Lindos. (48) May 3, 1919.
Eisenbetonschiffbau. (80) Serial beginning May 17, 1919.
Der deutsch-rumänische Werftbau Giurgiu.* E. Foerster. (48) Serial beginning June 7, 1919.
"Formstabile." Schiffskörper.* Ernst Foerster. (48) Serial beginning July 19, 1919.

Mechanical.

Problems in the Utilization of Fuels; Economic Use of the Poorer Grades of Coal and Oils. Raymond F. Bacon and William A. Hamor. (19) Serial beginning Oct. 11, 1919.
Petroleum Refining.* R. W. Cunningham. (From *Jour. Soc. Automotive Engrs.*) (19) Nov. 8, 1919.
Heat Treatment of 155-mm. High Explosive Shell.* William J. Merten. (105) Nov. 26-Dec. 3, 1919.
A British Air Limousine.* (120) Nov. 27, 1919.
The Problems in Designing an Engine Camshaft.* (120) Serial beginning Nov. 27, 1919.
The Static Head Turn Indicator for Aeroplanes: An Instrument Which Enables an Aviator to Find His Way in a Fog. Sir Horace Darwin. (From paper read before the Royal Aeronautical Soc.) (19) Nov. 29, 1919.
A New Type of Hydraulic-Turbine Runner.* Forrest Nagler. (55) Dec., 1919.
Air Pumps for Condensing Equipment.* Frank R. Wheeler. (55) Dec., 1919.
Calculations Relating to High Pressure and High Temperature Steam with Interheating for Power Generation.* W. M. Selvey. (77) Dec., 1919.
Carbon Dioxide Recorders; Aids to Fuel Economy. (118) Dec., 1919.
High-Speed Gearing: Widened Application of the Turbine. (118) Dec., 1919.
Slow-Speed Tests of Kingsbury Thrust Bearings.* H. A. S. Howarth. (55) Dec., 1919.
Tests of the Unaflow Pumping Engine.* D. A. Decrow. (28) Dec., 1919.
Combustion of Heavier Fuels in Constant-Volume-Type and Superinduction-Type Engines. Leon Cammen. (55) Dec., 1919.
Flow of Water Through Condenser Tubes.* W. L. De Baufre and M. C. Stuart. (55) Dec., 1919.
The Hvid Engine and the Fuel Problem.* E. B. Blakely. (55) Dec., 1919.
Waste Heat Boilers Produce Sufficient Steam to Furnish All the Power Required in a Cement Plant from the Exhaust Gases of the Cement Kilns. F. G. McKelvy. (67) Dec., 1919.
New York-London Airship Line Service Is Planned.* Allen Sinsheimer. (120) Dec. 4, 1919.
Moisture in Blast-Furnace Coke. William H. George. (22) Dec. 5, 1919; (57) Jan. 2.
Consumption of Fuel and Raw Materials in the Manufacture of Pig-Iron and Steel. (22) Dec. 5, 1919.
Manufacture of Pure Naphthaline from Coal Tar. F. A. Davy. (22) Dec. 5, 1919.
Commercial Coal Testing. J. Devlin. (26) Dec. 5, 1919.
Fuel Blending, the Sandwich System.* E. W. L. Nicol. (19) Dec. 6, 1919.

* Illustrated.

Mechanical—(Continued).

Water-Gas Manufacture in a Small Gas-Works.* J. W. Gibson. **(66)** Dec. 9, 1919.
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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

SECOND PROGRESS REPORT OF THE SPECIAL COMMITTEE TO REPORT ON STRESSES IN RAILROAD TRACK

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J. E. WILLOUGHBY

NOVEMBER 26TH, 1919.

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V.—Transmission of Pressures in Ballast.

A.—Analytical Discussion.

B.—Experimental Work in Laboratory.

C.—Discussion of Results of Tests.

To the American Society of Civil Engineers:

The Special Committee to Report on Stresses in Railroad Track herewith presents its second progress report.

I.—Introduction.

1.—Preliminary.—As was stated in the first progress report under date of November 3d, 1917, the Committee has been co-operating with the Special Committee on Stresses in Track appointed by the American Railway Engineering Association since the organization of the Joint Committee, June 3d, 1914. As the Committee of the American Railway Engineering Association consists of the members of the Special Committee of the American Society of Civil Engineers, eighteen in all, and three other members of the American Railway Engineering Association who do not hold membership in the American Society of Civil Engineers, the work, with the authorization given by the two Societies, has been carried on as one committee. This report is presented simultaneously to the two Societies. In recognition of the financial support given the Committee, the report is also being presented to the American Railroad Association.

It was early realized by the Committee that an adequate report on stresses in railroad track must be based largely on experimental data derived from extensive tests on standard railroad track, and that in view of the complexity of the action of track under load and the variability of the conditions to be found in track and load the work of conducting experiments and reducing the data would necessarily require a large amount of time and effort. An important element in the work, which has involved expenditure of time, effort, and money, has been the development of methods of conducting the tests and of devising the instruments and apparatus. It has been recognized from the start that in obtaining data on the action of track under the variable conditions of both track and load, great refinement of method was not possible and it was important to make tests under conditions of railroad service as nearly normal as is possible, utilizing also of course the data of laboratory investigations where conditions would not permit satisfactory experiments in the field.

The first progress report of the Committee was published by the Society in Vol. LXXXII., p. 1191, of the *Transactions,* (1918) and also in the *Proceedings* for January, 1918, p. 55; also in Vol. 19 of the *Proceedings* of the American Railway Engineering Association (1918) and in *Bulletin No. 205* of the Association. In this first report the action of the track as an elastic structure is discussed and a method of analysis for determining the effect of single wheel loads and of combinations of wheel loads is developed; the method of conducting the tests and the nature of the instruments used are described; and the

tests to determine the stresses in rail developed by static loads and moving loads under a variety of conditions of track and load are described and the data discussed. In particular, the results with several types of locomotive running at a variety of speeds on rails of several weights are given in some detail. Track depression and rail profiles under a variety of loadings are presented, and the properties of track as an elastic structure determined for a variety of conditions are reported. The report relates principally to stresses in rail and to the general elastic conditions of the track.

Conditions existing during the war greatly impeded the progress of the work of the Committee, and of course only such work was undertaken as could be done without interference with any activity or agency helpful in the prosecution of the war. Even since the war closed the conditions have been very unfavorable for carrying on experimental work. The limitations relate to both the use of railroad equipment and the supply of assistance for continuous work.

The work reported herein includes the results of tests with one type of freight locomotive and one type of passenger locomotive on the St. Louis-San Francisco Railway to determine stresses in rail in relation to speed and counterbalance effect, and also the results of similar tests with one type of freight locomotive on the Illinois Central Railroad. The report gives the results of tests on the Illinois Central Railroad and the Chicago, Milwaukee and St. Paul Railway to determine the depression of track under given loads and to find the depression and flexure of ties and their action under load for a variety of conditions found in track. The tests conducted in the Laboratory of Applied Mechanics of the University of Illinois with a view of finding the methods and principles involved in the transmisson of pressure from one or more ties downward and laterally through ballast materials are reported and an analytical consideration of the transmission of pressure is given. The report is presented under the following headings: Tests to Determine the Effect of Speed and Counterbalance on Stresses in Rail; Track Depression; Depression, Flexure and Bearing Pressure of Cross-Ties; and Transmission of Pressure in Ballast.

The Committee is continuing work on the subject assigned to it.

2.—Acknowledgment.—Funds for use in carrying on the work of the Committee have been taken from the contributions made by the United States Steel Corporation, the Bethlehem Steel Company, the Lackawanna Steel Company, and the Cambria Steel Company, acknowledgment of which was made in the first progress report. The Committee wishes to express appreciation of the appropriation of a fund by the American Railroad Association for its use in 1919 and 1920.

The co-operation of railroad companies in furnishing facilities for the test work has itself been a large contribution. The Illinois Central Railroad, A. S. Baldwin, M. Am. Soc. C. E., Vice-President, and F. L.

Thompson, Chief Engineer, gave the use of its tracks and of locomotive, cars, and crews for the tests made north of Champaign, Ill. The St. Louis-San Francisco Railway, F. G. Jonah, M. Am. Soc. C. E., Chief Engineer, and V. K. Hendricks, M. Am. Soc. C. E., Acting Chief Engineer, gave the use of track, locomotives, and crews for the tests made near Springfield, Mo. The Chicago, Milwaukee and St. Paul Railway, C. F. Loweth, M. Am. Soc. C. E., Chief Engineer, gave the use of track, locomotives, cars, and crews for the tests at Deerfield, Ill., and Libertyville, Ill.

War conditions have made it difficult to maintain a corps for the work—all who had formerly been engaged on the work went into war service. Mr. H. R. Thomas, who, as Assistant Engineer of Tests, had been connected with the testing operations from the beginning, was in direct charge of the field work in the tests on the St. Louis-San Francisco Railway, but was soon after called into Government war service. Mr. N. E. Ensign, Associate in Theoretical and Applied Mechanics in the University of Illinois, conducted the field tests on the Illinois Central Railroad and the Chicago, Milwaukee and St. Paul Railway and has rendered important service in the supervision of reducing the data on track depression and tie flexure and in interpreting the results, as well as in other parts of the work. Mr. M. L. Enger, Professor of Mechanics and Hydraulics in the University of Illinois, has been responsible for the experimental work on transmission of pressure in ballast; his previous study of transmission of pressure in granular materials brought to this work an experience which has made it possible to carry out the laboratory investigation on transmission of pressure through ballast so satisfactorily. Credit is given Professor Enger for interpreting the data of the tests with ballast and analyzing the problem; he is chiefly responsible for the chapter on "Transmission of Pressure in Ballast". Mr. E. E. Cress, Assistant Engineer of Tests, since January, 1919, has given very efficient service in the preparation of material for the report and in the study and interpretation of data—his thoroughness, familiarity with details, and keen grasp of the problems have been very helpful. Others have assisted in the work from time to time and all have given loyal and careful service.

The University of Illinois has continued to co-operate in the work by giving the use of laboratory, shop and office facilities and through the service of members of the staff of the Engineering Experiment Station from time to time.

II.—Tests to Determine the Effect of Speed and Counterbalance on Stresses in Rail.

3.—Purpose of Tests.—In the first progress report it was stated that analysis alone can give little real information on the important subject of the effect of speed of locomotive and train in increasing the

stresses in track, and that reliance must be placed upon experimental data to determine the influence which speed exerts in this matter. The increase in stress in rail with increase in speed as found from the tests reported was given in a general way for points at and between the wheels of the six locomotives used in the tests. No detailed study of the effect of speed was made, however, and the conditions of the tests were such that the effect of the counterbalancing of the locomotives was masked or not brought out. For simplicity of test and to avoid the introduction of variables which had no bearing on the problems then under consideration, all the runs in the tests reported were made with the counterweight of the front driver in its lowest position as it passed the middle one of the three instruments placed on one rail. The result of this arrangement was that the counterbalance effect existing differed for the several instruments and for the several wheels, but the stresses found at any wheel were approximately the same as the average stress throughout the revolution of the wheel, though it is probable that for some drivers the values found were somewhat larger than this average and for others somewhat smaller. No systematic variation due to position of counterweight was found in the results.

In pursuance of the programme of the Committee, tests have now been made to find the variation in stress in rail throughout the revolution of the drivers and to attempt to separate in some measure the effect of counterbalance from the effect of speed alone. In doing this, it was thought best to include a type of locomotive in which difficulty has been found in placing the desirable amount of counterweight on the main driver but in which, instead, the deficiency of counterweight has been added to the other drivers, making a badly balanced locomotive. The use of this class of locomotives had caused considerable injury to the rail of the railroad company; these locomotives were thought therefore to be extreme in the effects of speed and counterbalance. The counterbalancing of the other types of locomotives used, the Pacific and the Mikado types, is not so difficult a problem in design. The use of the Mikado type locomotive also permitted the tests to be connected up with the tests previously made on the Illinois Central Railroad.

The tests were conducted in the manner described in the first progress report for moving-load tests, the strains in the rail being measured with the stremmatograph.

4.—The Problem of Counterbalancing the Locomotive.—No attempt is made in this report to go far into the analytical side of the problem of the counterbalance and its effect on track. A brief review of the method of calculation commonly used and of the terms herein employed may be of advantage to the reader. To treat the matter in a thorough manner would involve long and complicated mathematical analyses and examples and would require the discussion of a number of elements on which there seems not to be agreement.

The moving driving parts of a locomotive are usually divided into (*a*) reciprocating parts and (*b*) rotating parts. The reciprocating parts include such parts as the piston and piston rod, cross-head, and a portion of the main rod (connecting rod). The rotating parts include crank pins, crank pin hubs, side rods, the portion of the main rod considered to contribute to rotational effects, etc. The motion of these reciprocating and rotating parts produces a dynamic effect on the locomotive and track, and in designing the locomotive, the attempt is made to counterbalance in such a way as to reduce the dynamic effect, as far as may seem practicable, by adding a counterbalancing weight to the drivers at a location opposite the crank pin.

To help in clearness of expression, the following distinction between counterweight and counterbalance will be made in this report. Counterweight will be used as the weight applied or added to the driver at a point opposite the crank pin for the purpose of balancing or helping to balance the rotating and reciprocating parts. The terms underbalance and overbalance will be used for the deficiency and the excess, respectively, of the counterweight as compared with that necessary to balance the rotating parts or to balance the rotating and reciprocating parts. The term counterbalance will be used to indicate the general condition of underbalance or overbalance as it exists in a given driver. The term counterbalancing will be applied to the general problem of endeavoring to balance the rotating and reciprocating parts.

The vertical effect of a lack of balance of the rotating parts is to increase or decrease the pressure of the drivers on the rails and to vary the pressure upward on the equalizer bars and the frame of the locomotive. A lack of balance for the reciprocating parts has little direct effect on the vertical pressures on the rail at the high and low position of the counterweight, though due to the acceleration of the piston and cross-head it may have a modifying influence on the main driver in certain portions of the revolution of the driver. A lack of balance for the combination of reciprocating and rotating parts produces strains in the locomotive frame and horizontal movements of the locomotive such as nosing. Underbalance and overbalance produce similar effects. It is evident that the counterbalance cannot be made to produce both the minimum vertical effect and the minimum horizontal effect. The methods in use attempt to compromise between the two. The practice in locomotive design is to counterbalance for all rotating parts and for a portion of the reciprocating parts, the proportion of the latter varying from one-half to two-thirds. It is evident, then, that so far as vertical pressure on track is concerned, this practice results in general in overbalancing the rotating parts.

In some types of locomotive other difficulties are found. The diameter of driver may be so small and the weights of the rotating and reciprocating parts so great that there is not space on the main driver

to place the necessary counterweight even if lead is used for the purpose. In such cases it is the practice to place as much counterweight on the main driver as practicable and to make up the deficiency by placing an extra amount of counterweight on the other drivers, dividing this amount equally among these drivers. The result is that the main driver may be underbalanced even for the rotating parts and the other drivers will have their overbalance for rotating parts increased. The effect on the track structure may be very marked, even though the effect on the locomotive itself may not be noticeable.

Another counterbalancing device sometimes used in such a type of locomotive is a counterweight, known as a bob, which is attached to the driver axle inside the bearings. On account of limitations of space in the design of frame commonly used, the radius of rotation of the bob is relatively small, and its weight must be correspondingly large, thus adding to the driver load at low speeds.

The vertical or horizontal pressure developed by the unbalanced rotating and reciprocating parts is called the dynamic augment. This dynamic augment is of course a function of the speed, increasing as the square of the speed.

The formula generally used for calculating the dynamic augment is the formula for centrifugal force,

$$C = \frac{W v^2}{g r} \quad \text{......................} (12)^*$$

in which

W = the weight of the rotating or reciprocating part for which the dynamic augment is desired, or the unbalanced part of the rotating parts in case the resulting rotational effect is wanted;

g = the acceleration of gravity;

v = the rotational velocity or speed of the part;

r = the radius of the circle taken by the center of gravity of the rotating part.

It is convenient to transfer all weights to the equivalent weight at the center of the crank pin and to use the radius of the circle taken by the center of the crank pin relatively to the center of the driver.

The equation implies consistent units, and the values may be taken in pounds, feet, and seconds, with g as 32.2 ft. per sec. per sec. If V is the speed of the locomotive in miles per hour, the speed in feet per second will be $\frac{4.4}{3} V$. The rotational speed of the crank pin v is obtained by multiplying this by the ratio of the radius of the crank pin circle r

* This equation number follows the last number used in the first report, p. 1206, *Transactions*, Am. Soc. C. E., Vol. LXXXII, 1918.

to one-half the diameter of the driver. The distance of the counterweight from the center of the driver will be greater than the radius of the crank pin circle, and a weight of equivalent rotational effect for a radius r may be used, the equivalent weight being found by multiplying the counterweight by the ratio of the rotational radius of the center of the counterweight to that of the crank pin. For determining the vertical dynamic augment, W should include the excess or deficiency of the rotating parts, and should not include the reciprocating parts, a portion of the main rod being taken as a rotating part. The part of the weight of the main rod which should be considered as an equivalent rotating weight at the crank pin may be determined by the principles of mechanics.

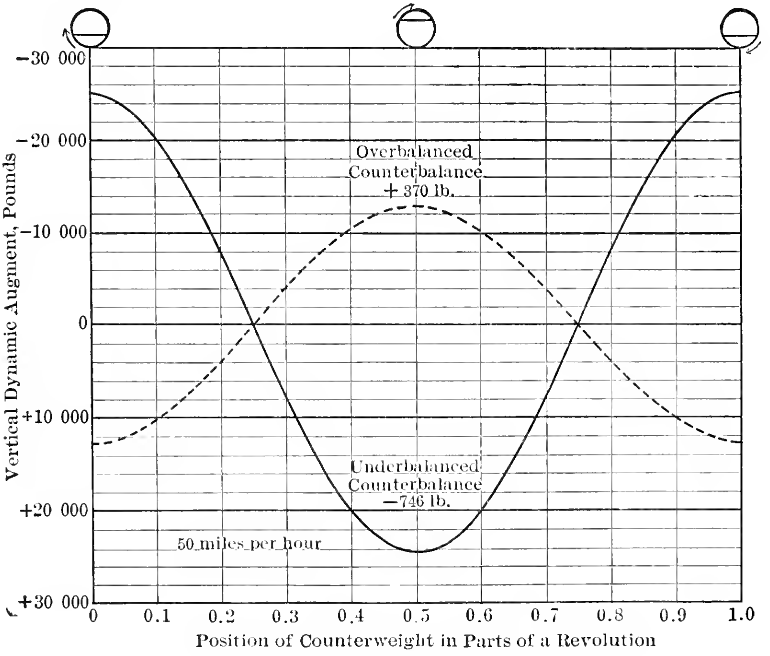


FIG. 1.—VERTICAL COMPONENT OF DYNAMIC AUGMENT FOR OVERBALANCE AND UNDERBALANCE OF ROTATING PARTS.

For determining the horizontal dynamic augment, the weight of the reciprocating parts should be included in determining the unbalanced weight W. In making the calculations, the center of gravity of the rotating part is used in getting the radius of rotation.

Fig. 1 gives, through a complete revolution, the values of the vertical component of the dynamic augment for an underbalance of 746 lb. at the crank pin circle and also for an overbalance of 370 lb. at the crank pin circle for a speed of 50 miles per hour, the diameter

of the driver being 60 in. and the radius of crank pin circle being one-half the radius of the driver. For the counterweights at one-fourth of a revolution from the low position (90°) the vertical dynamic augment for both underbalance and overbalance is zero, as is that at three-fourths of a revolution (270°). The position giving the maximum downward pressure of an underbalanced counterweight gives the maximum upward pressure of an overbalanced counterweight.

The fact that the center of gravity of the rods and other rotating parts is not in the same vertical plane as is the counterweight or the rail is not usually taken into account. The distributing forces are said to be slight in comparison with the principal rotating and reciprocating forces. The following shows that this element of the problem may need attention.

The plane of rotation of the side rod is some distance outside the plane of the counterweight, the main rod is still further away, and the part of the pin passing through these rods is also well outside the driver. The result of this eccentricity of position is to increase the effect of the dynamic augment at the central plane of the counterweight, and to require a greater amount of counterweight than would be necessary if these parts and the counterweight were in the same plane. The amount of this increase, in terms of the dynamic augment calculated by the formula given for dynamic augment, is determined by the ratio of the horizontal distance between the center of the counterweight and the center of the rod or other rotating part to the horizontal distance between the centers of the companion drivers. For the locomotives of the three types used in the tests herein reported—the Santa Fe, Pacific, and Mikado—this ratio, found from the dimensions of the parts, averaged about 0.11 for the side rod and the part of the pin within the side rod, and 0.23 for the main rod and the part of the pin within the main rod; that is, the vertical dynamic augment effect at the vertical plane through the center of the counterweight produced by the rotating parts outside of the driver, is 11% greater in the case of the side rod and its part of the pin, and 23% greater in the case of the main rod and its pin, than will exist at the plane of these rods as found by the formula for dynamic augment and centrifugal force. The value of the dynamic augment of these rods and pin calculated by the usual formula must then be increased in the proportion of 11% for the side rod and 23% for the main rod, or the weights of these parts may be considered to be that much larger in determining the underbalance or overbalance.

For the main driver the effect so found is considerable, affecting the amount of counterweight required; a seeming overbalance for rotating parts as judged by the method of calculation generally used in design may become an underbalanced wheel, while for an underbalanced main driver the deficiency in counterweight may be considerably greater than

that found when this eccentricity of position is not taken into account. For drivers other than the main driver the effect is much smaller and may not need consideration.

The foregoing discussion takes the dynamic augment back to the center of the counterweight; the center of the counterweight in locomotives of the types used is generally outside the center of the rail and the point of contact between wheel and rail, and the effect of this is to increase by a small amount the resulting pressure on the rail due to overbalance or underbalance; in the cases under consideration this would probably not increase the dynamic augment by more than 3 per cent. It must be concluded, however, that the location of the rods away from the plane of the counterweight may become of importance in the calculations of the counterbalance of the main driver and should not be overlooked.

The effect due to the rods and the counterweight of a given driver not being in the same plane with each other extends also to the companion driver on the other rail, decreasing the vertical pressure of the companion driver when the pin of the other driver is down and increasing it when the pin is up. It will be seen that the effect upon the companion driver comes at a point in its revolution which is away from the maximum and minimum effect of its own counterbalancing, and hence this element of the problem may not particularly affect the value of the maximum pressure developed by the driver. In case a main driver is balanced for its own masses only, the effect of the rods on its companion driver will be to put it out of balance.

A further condition complicates the problem: the crank pins of the left side of the locomotive are set 90° behind those on the right side. This adds to the stresses in the locomotive and may be expected to produce lateral bending in rails.

In judging of the vertical rail pressure produced by partially balanced rotating parts or by overbalanced rotating parts, it may be sufficiently near the truth to consider that the vertical dynamic augment produced by the excess or deficiency of counterbalance of the rotating parts acts as a vertical pressure on the rail at each driver. This may be expected to be approximately true even when the adjacent drivers have quite different dynamic augment, since the change in depression of the track structure due to the added or decreased pressure on the rail, is small in comparison with the total amount of deflection of the locomotive spring produced by the weight of the locomotive tributary to the given driver, and hence a movement of the wheel downward with the increase in track depression produced by the dynamic augment will result in reducing the load transmitted from the locomotive frame only a relatively small amount and the action of the equalizing levers may be expected to minimize even this effect. It seems proper, then, in making calculations, to consider the vertical dynamic augment of

each driver as being separate downward or upward loads which may be added algebraically to the individual driver loads on the rail. How much this will be modified by the spring of rail and movements of locomotive springs and how much will be transmitted to other wheels by the equalizing levers cannot well be determined by analysis.

Having calculated the vertical dynamic augment of the rotating parts (using the underbalance or the overbalance), the vertical pressures so obtained may be used as positive or negative loads at the wheel points, and calculations for stress in rail may be made for such loads by the methods given in the first progress report of the Committee under "Combination of Wheel Loads". Illustrations of the use of this method in the calculation of resulting loads and stresses may be found in the discussion of test results which follows.

As the tests for effect of counterbalance were made with the locomotive running with steam shut off, the effect of cylinder pressure does not enter into the results discussed except so far as there may have been resisting pressure developed in the cylinders. For locomotives working under steam pressure, the effect is to increase the downward pressure of the main driver by the vertical component of the main rod tension or compression. For the dimensions of the main rod in the locomotives used this vertical pressure at the up and down points of the crank pin would be from 0.10 to 0.14 of the cylinder pressure at mid-stroke, this vertical pressure presumably being all taken by the main driver.

5.—The Locomotives.—In the tests on the St. Louis-San Francisco Railway two types of locomotives were used, the Santa Fe type freight locomotive and the Pacific 1060 type of passenger locomotive. Slight variations were made in these locomotives by lightening reciprocating and rotating parts of the Santa Fe and Pacific types and by changing the position of the equalizer pin of the Pacific type. The Santa Fe type locomotives were new locomotives, having been in service less than a year. The Pacific type locomotives had been in service about two years.

Fig. 2 gives the spacing of drivers and the wheel loads. The diameter of the drivers in the Santa Fe type was 60 in. and that in the Pacific type 73 in. The crank pin was 15 in. from the center of driver in the Santa Fe type, and 14 in. in the Pacific. The corresponding distance for center of counterweight was 16½ in. in the Santa Fe type and 20¼ in. for the main driver and 25¼ in. for the other two drivers in the Pacific type.

In Table 1 are found the weights of the reciprocating and rotating parts of the Santa Fe locomotive as given by the Mechanical Department of the St. Louis-San Francisco Railway, together with the calculated required counterweights, the amount of counterweight used and

the excess or deficiency of counterbalance by the method of calculation used by the Railroad Company. It will be noted that 60% of the weight of the reciprocating parts is included in the counterbalancing calculations and that this weight is divided among four drivers and not among all five, a matter which affects the vertical dynamic augment only as the overbalance or underbalance of the several wheels for rotational parts is affected. Table 1 also gives the excess or deficiency of counterweight needed to balance the rotating parts only, since this excess or deficiency is the principal factor affecting increase or decrease in vertical pressure on the rail.

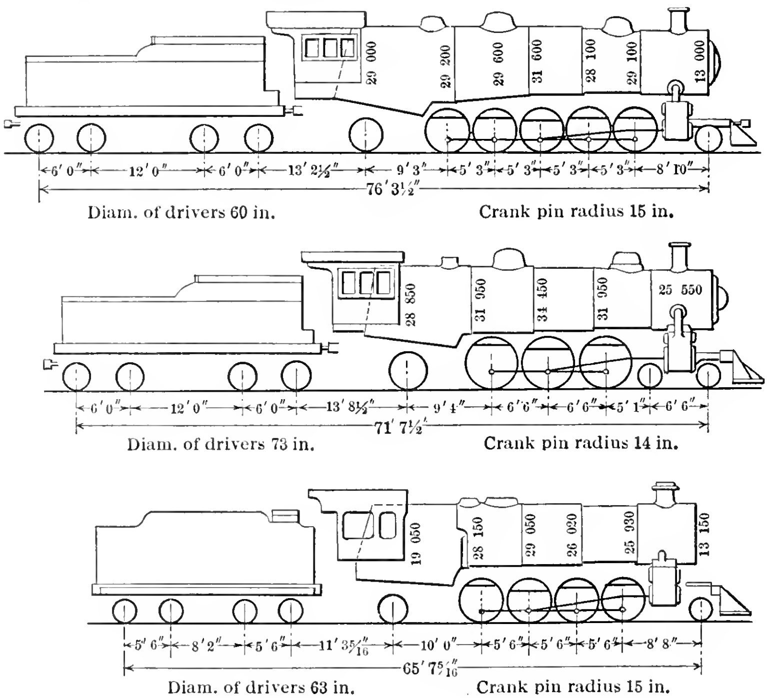


FIG. 2.—DIAGRAMS OF THE THREE TYPES OF LOCOMOTIVES.

There may be of course some question concerning the amount or proportion of the weight of the main rod which contributes to the rotational effect. The excess or deficiency of counterweight needed to balance the rotating parts only, as given in Table 1, is the value usually considered in designing practice, and is found without taking into consideration the effect of the rods and pin not being in the same vertical plane with the counterweight of the driver. The method outlined in the preceding article for taking this variation of position of the dynamic forces into account involved adding to the weight of

TABLE 1.—WEIGHTS OF ROTATING AND RECIPROCATING PARTS, IN POUNDS—SANTA FE TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

RECIPROCATING PARTS.

Piston	803
Cross-head	860
48% main rod, weight on cross-head pin	657
	2 320

$$\frac{0.60 \times 2\ 320}{4} = 348$$

ROTATING PARTS.

Driver number	5	4	Main	2	1
60% of weight of reciprocating parts	348	348	......	348	348
Main rod, weight on crank pin	......	......	735	......	......
Side rod, weight on crank pin	190	583	740	504	190
Crank pin	155	162	420	162	140
Crank pin hub	189	196	305	196	189
One-half eccentric crank	......	......	60	......	......
Total	882	1 289	2 260	1 210	867
Equivalent weight required at center of counterweight, average taken for two corresponding wheels	794	1 135	2 054	1 135	794
Weight used	812	1 156	1 376	1 156	812
Difference between weight required and weight obtained	+ 18	+ 20	− 678	+ 20	+ 18
Equivalent difference at crank pin circle	+ 20	+ 22	− 746	+ 22	+ 20
Overbalance or underbalance at crank pin circle for rotating parts only	+ 368	+ 370	− 746*	+ 370	+ 368

* This becomes 1 042 lb. if the effect of the rods and pin not being in the plane of the counterweight is considered to be as described in the text.

the side rod and its part of the pin 11% of the weight of these parts as being approximately the effect for the average of the dimensions of the three types of locomotives used in the tests, and to the weight of the main rod used and its part of the pin 23% of the weight of these parts—this increased weight being considered to represent the weight to be used in determining the condition of counterbalance in the plane of the counterweight. Applying these percentages to the parts affecting the main driver, the weight of the main rod coming on the crank pin and that of the side rod and also the parts of the crank pin in the main rod and the side rod, the underbalance of the main driver is found to be 1042 lb. instead of 746 lb.—a very great deficiency. For the other drivers the effect is not so great; there is a reduction in the amount of overbalance of 27 lb. for Drivers 1 and 5 and of 67 lb. for Drivers 2 and 4. It is not known how closely the weights of the locomotives used agree with the weights given in Table 1; the indications are that there are uncertainties in the weights and in their positions.

In Table 2 are given in the same way the weights of the reciprocating and rotating parts of the Pacific type locomotive as furnished by the Mechanical Department of the St. Louis-San Francisco Railway.

TABLE 2.—WEIGHTS OF ROTATING AND RECIPROCATING PARTS, IN POUNDS—PACIFIC TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

RECIPROCATING PARTS.

Piston	765
Cross-head	870
Main rod, weight on cross-head pin	535
	2 170

$$\frac{\frac{2}{3} \times 2\,170}{3} = 482$$

ROTATING PARTS.

Driver number	3	Main	1
Two-thirds of weight of reciprocating parts, divided among three drivers	482	482	482
Main rod, weight on crank pin	......	630	......
Side rod, weight on crank pin	225	680	224
Crank pin	155	405	150
Crank pin hub	142	217	142
One-half eccentric crank	......	60	......
Total	1 004	2 474	998
Equivalent weight required at center of counterweight, average taken for corresponding wheels	555	1 710	555
Weight used	525	1 605	522
Difference between weight required and weight obtained	— 30	— 105	— 33
Equivalent difference at crank pin circle	— 54	— 152	— 59
Overbalance or underbalance at crank pin circle for rotating parts only	+ 428	+ 330*	+ 423

* This becomes 76 lb. if the effect of the rods and pin not being in the plane of the counterweight is considered to be as described in the text.

Applying the method already outlined for obtaining the effect of the main rod and side rod at the plane of the counterweight by means of the factors found from the dimensions of the driver and rods, as just used for the main driver of the Santa Fe type locomotive, it will be found that instead of an overbalance of 330 lb. for the main driver, as given in Table 2, there will be an overbalance of 76 lb., or in effect nearly a balanced condition. The results of the tests indicate an underbalance in the main driver. There appears to be an uncertainty in regard to the accuracy of some of the weights given in this table. It should be noted that the effect upon the counterbalance calculations for the first and third drivers due to the plane of the side rod not being in the plane of the driver is not large, and the error due to neglecting this element is inconsiderable. It may be noted that the larger diameter of the driver of the Pacific locomotive makes the problem of counterbalance easier than for the Santa Fe type even at speeds considerably higher than the freight locomotive would be expected to take.

Fig. 2 also gives the spacing of drivers and the wheel loads of the Mikado locomotive of the Illinois Central Railroad. The diameter of the drivers was nominally 63 in., but the measured circumference was 195 in. Table 3 gives the weights of the rotating parts of the Mikado

locomotives as furnished by the Illinois Central Railroad. Here the consideration of the planes in which the parts rotate reduces the overbalance for rotating parts given for the main driver to what would appear to be an approximate balance. The results of the tests will be found to indicate an underbalance for the main driver instead of a balance or an overbalance.

TABLE 3.—WEIGHTS OF ROTATING PARTS, IN POUNDS—MIKADO TYPE LOCOMOTIVE OF THE ILLINOIS CENTRAL RAILROAD.

Driver number	4	Main	2	1
60% of weight of reciprocating parts	263	263	263	263
Main rod, weight on crank pin	......	630	......	......
Side rod, weight on crank pin	145	829	480	154
Total weight considered	408	1 722	743	417
Equivalent counterbalance weight at crank pin in excess of that required to balance crank pin and crank pin hub.	408	1 722	743	417
Overbalance at crank pin circle for rotating parts only..	+ 263	+ 263*	+ 263	+ 263

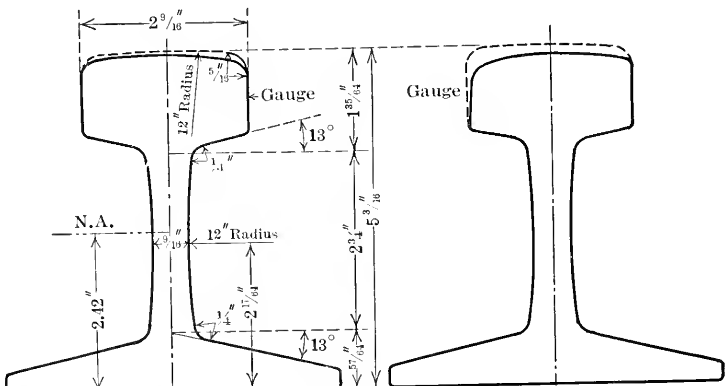
* This becomes an underbalance of 15 lb. if the effect of the rods and pin being in the plane of the counterweight is considered to be as described in the text.

It may be of interest to note that the dynamic argument for each pound of underbalance or overbalance considered to be concentrated at the crank pin for the three locomotives used amounts to 33.4 lb. for the Santa Fe type locomotive at a speed of 50 miles per hour, 30.3 lb. for the Pacific type at 60 miles per hour, and 24.5 lb. for the Mikado type at 45 miles per hour; for example, an underbalance of 746 lb. on the Santa Fe type gives a dynamic augment of 24 900 lb.

In all the tests the locomotives were considered to be in good condition. Tires were not worn, except for the main driver of the Santa Fe type (without flanges) which showed more or less wear. The locomotives were representative of those of the same class used on the two railroads.

6.—*The Track.*—The tests on the St. Louis-San Francisco Railway, made November 20th to December 7th, 1917, were conducted on a section of single track about three miles west of Springfield, Mo. The rail was 85-lb. Am. Soc. C. E. section, rolled in October, 1906. The rail section as worn (shown in Fig. 3) had a moment of inertia (I) of 29.1 in.^{4} about a horizontal axis, and of 6.8 in.^{4} about a vertical axis. The section modulus $\left(\frac{I}{c}\right)$ was 12.0 in.^{3} about a horizontal axis and 2.6 in.^{3} about a vertical axis. The ties were 6 by 8 in. by 8 ft., of oak, spaced about 20 in. apart center to center, twenty to a 33-ft. rail length. There were 15 in. of chats ballast of good quality. The track was in fair surface and alignment, and was used as it was found. It had not been tamped recently, but as freight trains are not run over this stretch of track the effect of traffic is not great.

The tests on the Illinois Central Railroad were conducted two miles north of Champaign, Ill., September 19th to 21st, 1918, on the southbound track used in the earlier tests reported in the first progress report of the Committee (see page 1237* of the first progress report), the location being that described as Section B. The rail was 85-lb. Am. Soc. C. E. section, laid in 1902. The rail section is given in Fig. 3. The properties used in the calculations were the same as those given in the first progress report, 27.0 in.^{4} for the moment of inertia about the horizontal axis and 11.1 in.^{3} for the section modulus for the remote fiber at the base of rail. The ties were the 6 by 8-in. by 8-ft. oak, ties which had been specially prepared for this stretch of track. They were spaced approximately 20 in. apart, 20 ties to a 33-ft. rail. On the section used in the test there was 12 in. of stone ballast. The track had not been tamped for some time and was not in the best condition of line and surface, but it was used in the condition found.



85 LB. A.S.C.E. (WORN) ST. LOUIS AND SAN FRANCISCO RAILWAY

85 LB. A.S.C.E. (WORN) ILLINOIS CENTRAL RAILROAD

Fig. 3.—Sections of Rails Used in Tests.

7.—The Conduct of the Tests.—The instruments used to determine the strains in the rail were the stremmatographs described in the first progress report, page 1224.* Four stremmatographs were used simultaneously. The methods employed were generally the same as those described in the previous progress report. Fig. 4 shows the position of the instruments as used in the tests on the St. Louis-San Francisco Railway. Set-ups *a, c,* and *d* were on the same rail, and Set-ups *b* and *e* were on the adjacent rail. It will be noted that in two set-ups, three instruments were on the rail on one side of the track and the fourth

* *Transactions*, Am. Soc. C. E., Vol. LXXXII.

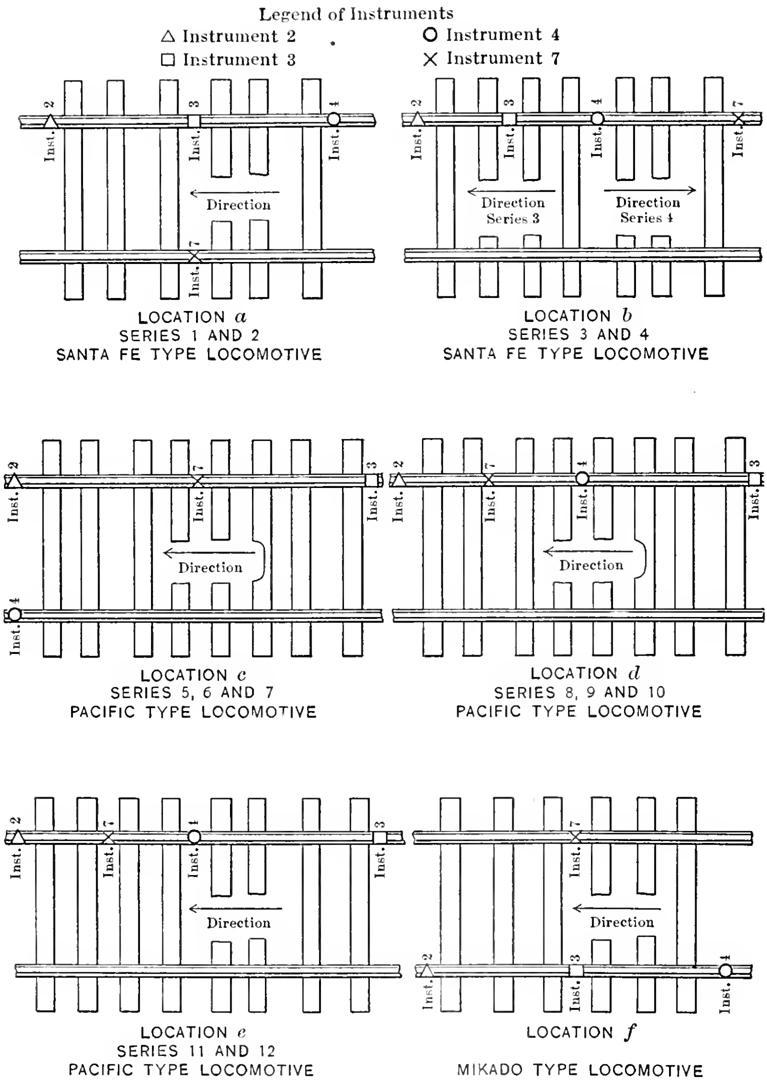


Fig. 4.—Position of Stremmatographs in Tests.

was on the rail of the opposite side. The instruments were spaced two, three, and four tie spaces apart.

In the tests on the St. Louis-San Francisco Railway, as it was a single-track stretch of railroad, the two sides of the track were presumably the same with respect to ballast and tamping.

In the principal tests made with the Santa Fe type locomotive, three stremmatographs were placed on the rail at the right side of the locomotive and one on the rail at the left side (see Fig. 4, location *a*). In the tests to determine the stresses developed at the two sides of the locomotive, the four instruments were placed on one rail, and part of the tests were made with the locomotive running in one direction and part in the other (see Fig. 4, location *b*). In the tests with the Pacific locomotive, the four instruments were placed on one rail (see Fig. 4, locations *c*, *d*, and *e*). In all runs steam was shut off as the locomotive approached the test section of track. The speeds were read from a speedometer in the cab connected with the tread of the trailer, the instrument being checked up by timing runs over a measured length of track. For each set of tests the order of speeds for consecutive runs was the same, three or four speeds being used together, and the record of each three or four runs at these speeds was made on one set of discs; new discs were then placed in the instruments.

The position of the counterweight with respect to one instrument was observed for each run. The effort was made to keep the counterweight at the same position with respect to the instrument for the three or four runs covering the three or four speeds used, and then to slip the drivers sufficiently to change the position of the counterweight about one-fourth of a revolution. The slipping of the drivers in stopping and starting, however, changed the position somewhat. The instruments were placed about one driver diameter apart so that for each instrument there was a different position of counterweight. Altogether the tests give a general distribution of position of counterweight over the entire revolution.

The extent of the tests on the St. Louis-San Francisco Railway was limited by reason of the difficulty in sparing the locomotives from service, the demands of traffic at the time being very great. A larger number of runs would have added much to the value of the information. The weather conditions were unfavorable much of the time.

The tests on the Illinois Central Railroad with the Mikado locomotive were made on the south-bound track, and in order to get the necessary distance to acquire high speeds, the locomotive was run northward. Three stremmatographs were placed on the west rail (left side of the locomotive) and one on the east rail opposite the middle one of the instruments. The arrangement is shown at *f* in Fig. 4. The three instruments on the one rail were placed about 63 in. apart, nearly one-third the circumference of a driver.

It should be noted that the rail on which these three instruments were placed was on the outer side of the double track and that, as is shown in the report of the tests on track depression, this side of the track was not in as good surface condition as the inner side. The order of the speeds was 5, 35, 25, and 45 miles per hour, and the four consecutive runs were recorded on the same discs. In all runs steam was shut off as the locomotive approached the test section of track. As with the other tests, the demand of traffic for locomotives was such as to limit the work of the tests. The data secured seem sufficient for general purposes; more tests would have given a wider range of information.

8.—Reduction of Data.—The process followed in the reduction of the data obtained by the stremmatographs in the moving load tests was the same as that which was described in the first progress report. The stremmatograph records were read with a microscope fitted with a micrometer eyepiece. Readings were taken for points in the record corresponding to the position of wheel over instrument and to a point between wheels. In reducing these measurements the readings were multiplied by the proper microscopic constant and then reduced to stresses by multiplying by a constant which involves the value of the moment of inertia and the position of the vertical axis of the rail section, the vertical distance of the needle-bar below the base of rail, the modulus of elasticity of steel (taken as 30 000 000 lb. per sq. in.), and the gauge length (which was 4 in.). A correction was also made to allow for the variation of moment and stress over the gauge length. To obtain the maximum stress at the middle of the gauge length the average stress over the gauge length for points corresponding to the position of wheel over instrument was multiplied by the factor 1.04, as was done with the tests recorded in the first progress report, so that the stresses reported at points of positive moment are stresses in pounds per square inch at the base of the rail at the middle of the gauge length. The variation over the gauge length at points of negative moment was slight and no correction was used for the stresses at such points.

In general, the readings of the two discs of an instrument, giving stresses on two sides of the rail, were averaged and the average was taken as the observation for that instrument for the given run for the given position of wheel. In case the record on one disc of an instrument was defective and that on the companion disc was clear, the one good record was generally also discarded. In case the record of a disc was clear enough to be usable, the record for all the wheels and all the runs on the disc was usually measureable, although the line made by the truck and trailer was less definite than that made by the drivers. Sometimes, however, not all of the record on a disc was clear; in this case the portion available was used. For some of the tests nearly one-

third of the records had to be discarded. It appears that the disc readings taken with the Santa Fe type locomotive were generally clearer than those taken with the Pacific type. The conditions of the tests on the Illinois Central were more favorable and the records were generally good. The records at points of negative moment were generally less clear than those at the wheels, and a larger proportion was discarded.

For any reading or observation, the position of the counterweight of the driver corresponding to the point in the record was found in terms of the part of a revolution of the driver beyond the last down position of the counterweight. This was done for each driver and also for trailer and front truck. In the reduction, the high point of the record was assumed to have been made when the wheel was directly over the instrument.

The readings of the stremmatograph records, the reduction of the data, and the location of the counterweight with respect to each instrument and each point in the record involved a large amount of work, as nearly 100 000 readings were made.

The accuracy of the records and their reduction is considered to be as good as that of the stremmatograph data reported in the first progress report.

It may be noted that for the rail used in the tests on both the St. Louis-San Francisco Railway and Illinois Central Railroad the stress at the extreme fiber of the head of rail is about 10% greater than that in the extreme fiber at base of rail. The latter has been used in giving results because the width of the base of rail makes the stresses due to lateral bending greater there than in the head of the rail and the lateral bending stresses are great enough to be significant.

9.—Tests on St. Louis-San Francisco Railway.—Table 4 gives information on Series 1 to 12 made on the St. Louis-San Francisco Railway. The injury done to rails by the Santa Fe locomotives soon after they were received from the builders had given the Railroad Company some concern, and the opportunity was taken to make tests with what was evidently a poorly balanced locomotive. The weight on the trailer of the Pacific locomotive seemed excessive, and for a wheel well away from other wheels the stress developed in the rail would be expected to be high. The bearing of the trailer at times had run hot. The tests were made to obtain information on the effect of speed and counterbalance with this type of passenger locomotive.

In Series 1, the order of runs in the tests was 5, 25, and 40 miles per hour for Locomotive No. 22, and 25, 50, 25, and 50 miles per hour for Locomotive No. 28. For Series 2, two sets were run,—the first at 5, 25, and 40 and the second at 25, 50, 25, and 50 miles per hour. In Series 3 and 4 the order 5, 25, and 40 was used. For all series with the Pacific type locomotive, the order was 5, 45, and 60 miles per hour.

TABLE 4.—TESTS ON THE ST. LOUIS-SAN FRANCISCO RAILWAY.

Series number.	Location of Test.	Type of locomotive.	Locomotive number.	Position of pin in equalizer bar.	Remarks.
1	First location....	Santa Fe	22, 28	....	General series with locomotive as received from builders.
2	" "	" "	19	....	Reciprocating and rotating parts lightened.
3	Second location..	" "	22	....	Instruments all under right side of locomotive.
4	" "	" "	22	....	Instruments all under left side of locomotive.
5	First location.	Pacific...	1061	Rear hole.......	Locomotive with stoker added.
6	" "	" ...	1061	Middle hole.....	Do.
7	" "	" ...	1063	Rear hole.......	Rotating and reciprocating parts lightened.
8	" "	" ...	1063	Middle hole.....	Do.
9	" "	" ...	1067	Middle hole.....	General series.
10	" "	" ...	1065	Rear hole.......	" "
11	Second location..	" ...	1066	Middle hole.....	" "
12	" "	" ...	1067	Rear hole.......	" "

The tests were not made in the order of the numbers of the series; instead, the locomotives were taken as the demands of traffic or matters of convenience permitted. In the discussion which follows the series are grouped for the consideration of effect of speed and counterbalance, effect of lightening rotating parts, stress under the two sides of the locomotive, and general comparisons.

10.—The Santa Fe Type Locomotive; Effect of Speed and Counterbalance.—The typical effect of the combination of speed and counterbalance upon stresses in rail for Series 1 with the Santa Fe type locomotives is shown in Fig. 5, which gives sample curves for the main driver taken from the plotted results of the tests with the Santa Fe type locomotive from the data of the instruments on the rail on the right side of the locomotive only. The ordinates of the diagram represent stresses at the base of the rail in pounds per square inch. The abscissas represent the position of the counterweight at the time the wheel passed over the instrument with respect to its down position, the scale being in fractions of a complete revolution of the wheel. The curves represent the average of the results of the several runs at each speed. For a speed of 5 miles per hour the values are represented by a straight line, since the variation from it is small. As the driver is underbalanced, in general the greatest stress in the rail is developed when the counterweight is at its high position. At a speed of 50 miles per hour, it is noted that the maximum value of the curve is 44 700 lb. per sq. in. and the minimum value 14 000 lb. per sq. in. The line marked "mean value of 50 miles per hour curve" is the average ordinate of the curve. The variation above and below this line may be considered to be due largely to the lack of balance of the rotating parts.

The difference between the mean value of the stress found from the curve for 50 miles per hour and the stress at 5 miles per hour may be considered to be largely the effect of speed without reference to effect of rotating parts, (quite frequently called impact effect or speed effect), though part may be due to lack of balance of rotating parts. The dotted line of the figure was obtained by the use of the common formula for the vertical pressure of a rotating part, the calculation here being modified to touch the curve for 50 miles per hour at its high and low points. It will be noted that the form of the observed curves is more pointed than is the curve calculated by analytical methods, and also that

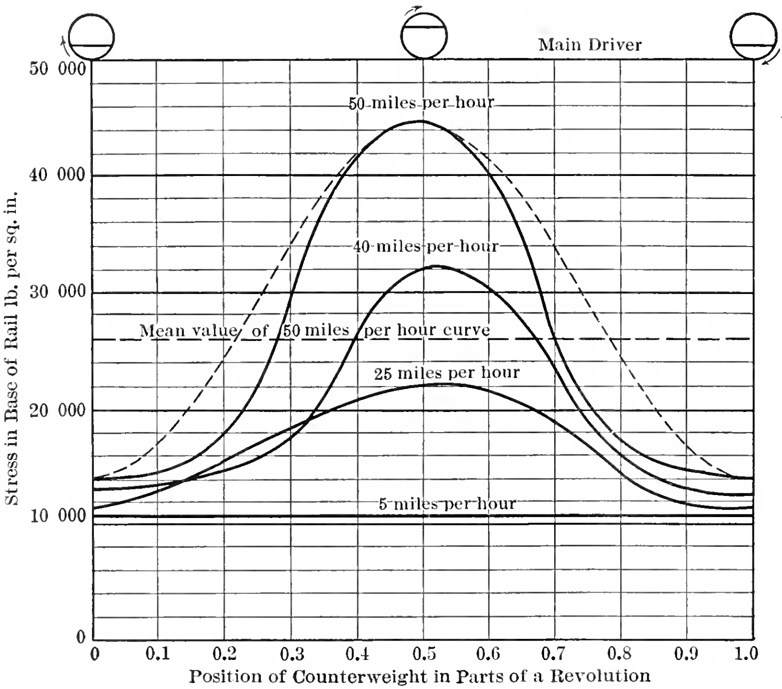


FIG. 5.—STRESS IN RAIL AT MAIN DRIVER OF SANTA FÉ TYPE LOCOMOTIVE THROUGHOUT A REVOLUTION.

the mean value of the curve is generally below the median point of the curve. These differences are characteristic of many of the tests, though it appears that there are as many cases where the observed curve is less pointed than the analytical curve as for more pointed curves.

As examples of the test data, the test results for Series 1 with the Santa Fe type locomotive for four speeds for the main driver and Driver No. 4, and for one speed for the other drivers and the trailer are plotted in Figs. 6 to 11. Results given by the several instruments are indicated by individual symbols, which are explained in Fig. 4. The curves representing the stress for a given speed throughout an entire revolution

were formed by first averaging the values of the plotted points in groups for each twentieth of a revolution and then drawing a curve to represent as well as possible the position and trend of these points. As in this series there were more runs at 25 miles per hour and less at 50 miles per hour than at the other speeds, the data points for a speed of 25 miles per hour are most numerous, and those for 50 miles per hour the least numerous, the number at the latter speed being only about half that at 5 miles per hour or 40 miles per hour. As may be expected, at a speed of 5 miles per hour the variation in stress due to other causes is so much greater than that due to effect of counterbalance as to mask any effect of counterbalance, and accordingly a straight-line average of all the points has been used for all the wheels for the speed of 5 miles per hour. In each case a line has been drawn above the average curve and one below it which together form the limits of a belt which includes most of the observed points. The distribution of these points vertically over the belt generally is fairly uniform when there are fifty or more points in the diagram. In some cases, with insufficiency of data, the points are quite scattered. The line representing the average ordinate for the curves is marked "mean value of curve"; the line representing the average stress at 5 miles per hour has also been drawn. The diagrams include the results for the instrument on the left rail, although as shown in Article 12 on "Comparison of Stresses under the Two Sides of the Santa Fe Type Locomotive", the stresses in rail on the two sides of the locomotive differed considerably.

Fig. 12 gives the stress in base of rail throughout a revolution of driver for all the drivers and the trailer for Series 1, obtained as described in the preceding paragraph. These curves then represent the average stress for any given position of counterweight. It should be borne in mind that the observed points are not always well distributed in the plots from which these average curves were formed (such as are shown in Fig. 9) and in some cases there is indefiniteness in the data, which makes the forming of the curve difficult and somewhat uncertain. It may be added that the numbers of observed points in the plots are generally not sufficient to establish very definitely the position of the maximum and minimum points on the curve with reference to the position of the counterweight in its revolution.

Fig. 13 gives the stresses in rail under the wheels for the high point and the low point of the curves of Fig. 12. The stresses for negative moment between wheels are also given; for some of the wheels no especially marked difference throughout the revolution was found and the mean of the observed stresses for negative bending moment is reported. Not enough difference was found under the front truck wheel throughout the revolution to warrant giving more than a straight-line average for the stress at this wheel. A similar condition was found under the trailer for a speed of 25 miles per hour, but at the

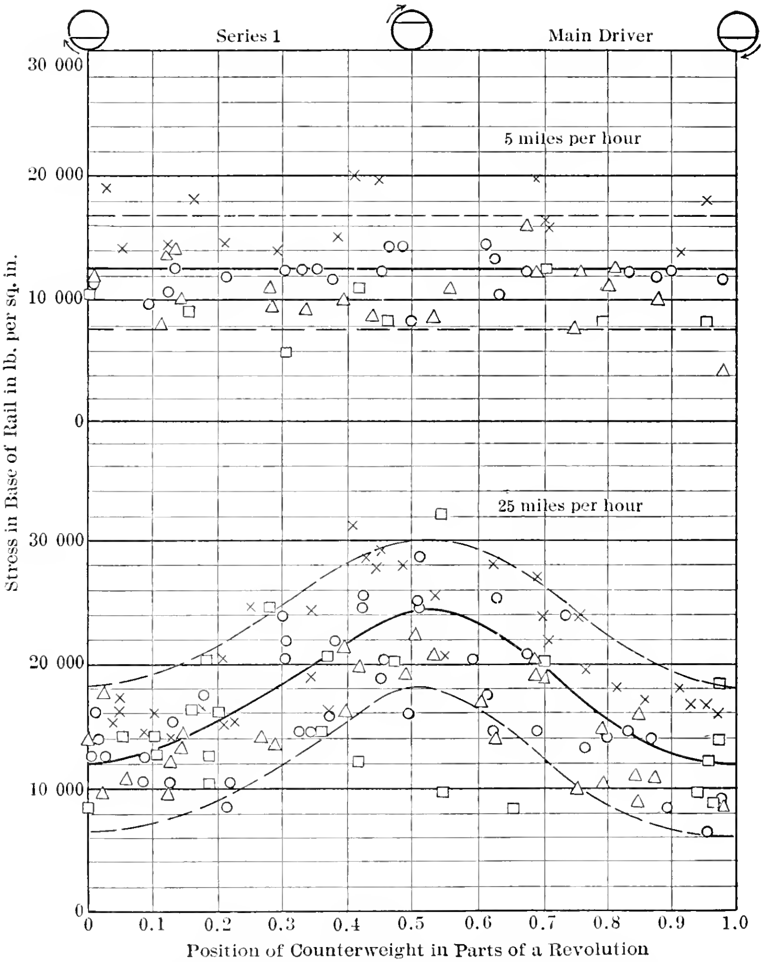


FIG. 6.—OBSERVED VALUES OF STRESS IN RAIL WITH SANTA FÉ TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

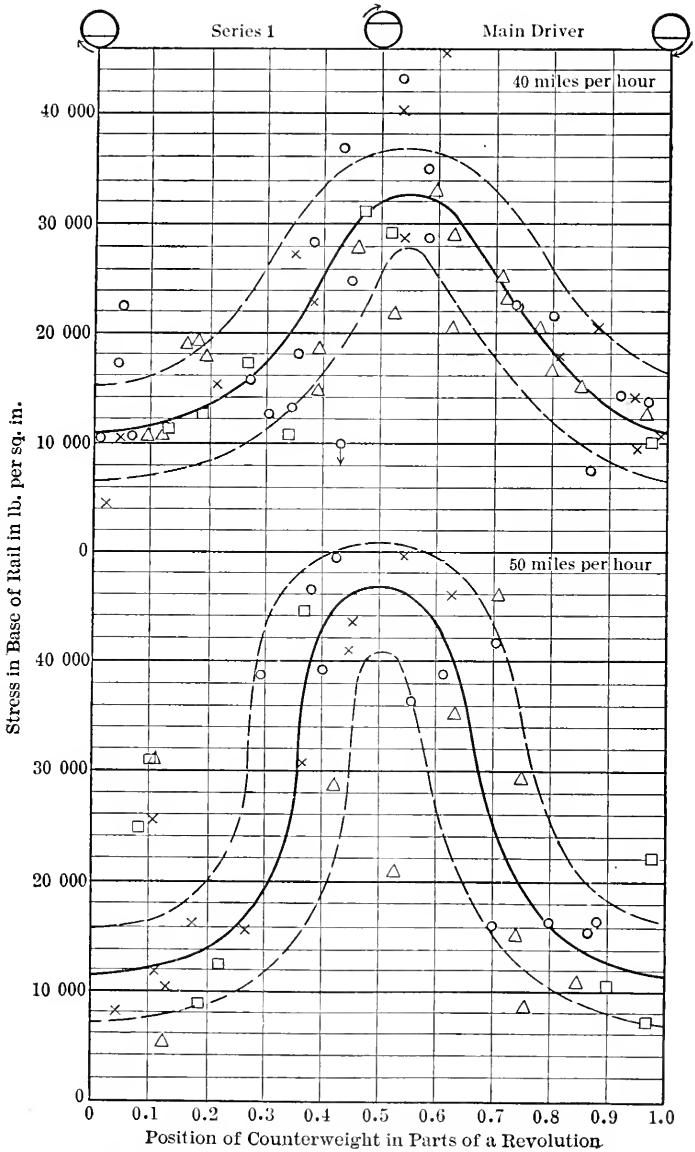


FIG. 7.—OBSERVED VALUES OF STRESS IN RAIL WITH SANTA FÉ TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

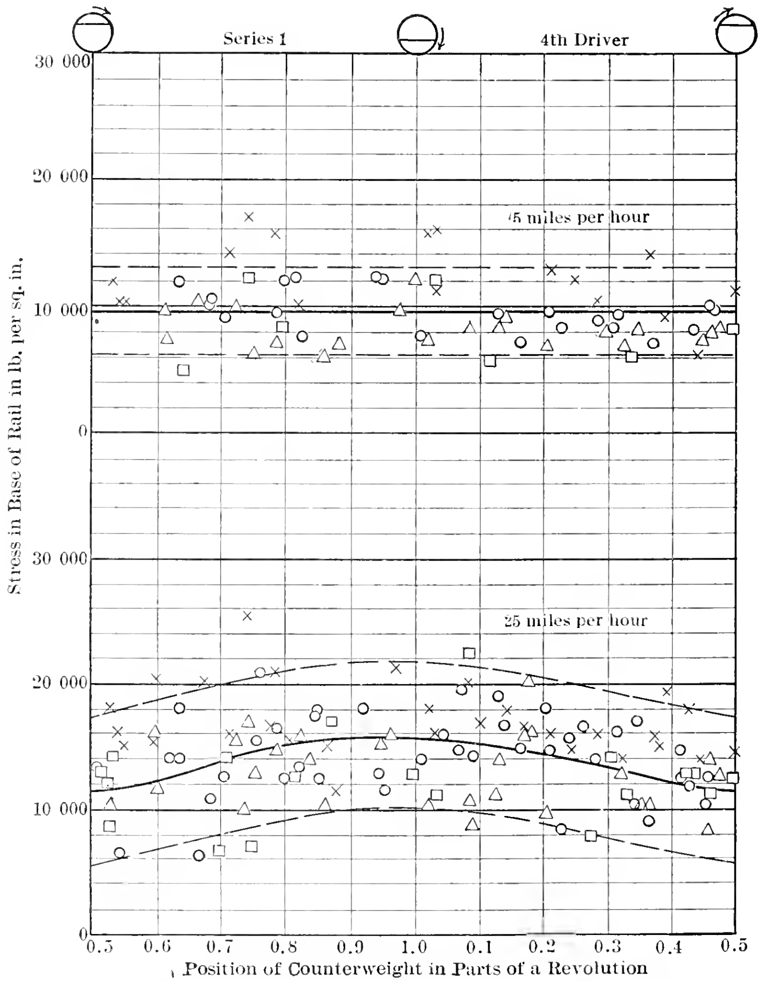


FIG. 8.—OBSERVED VALUES OF STRESS IN RAIL WITH SANTA FÉ TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

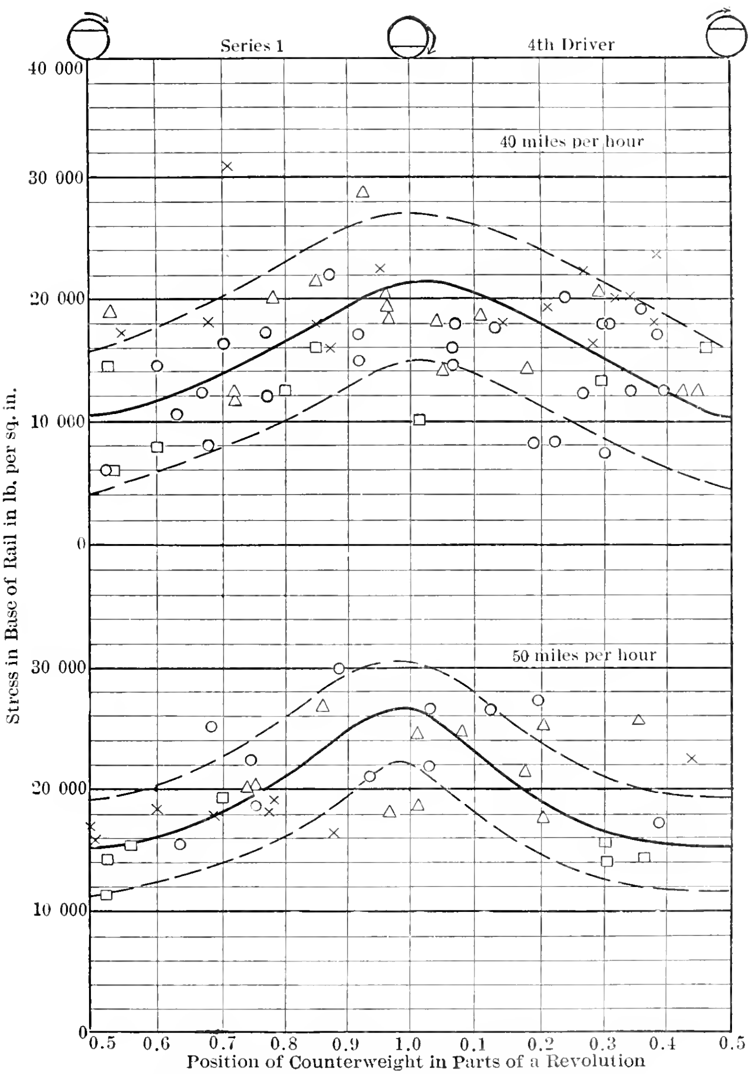


FIG. 9.—OBSERVED VALUES OF STRESS IN RAIL WITH SANTA FÉ TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

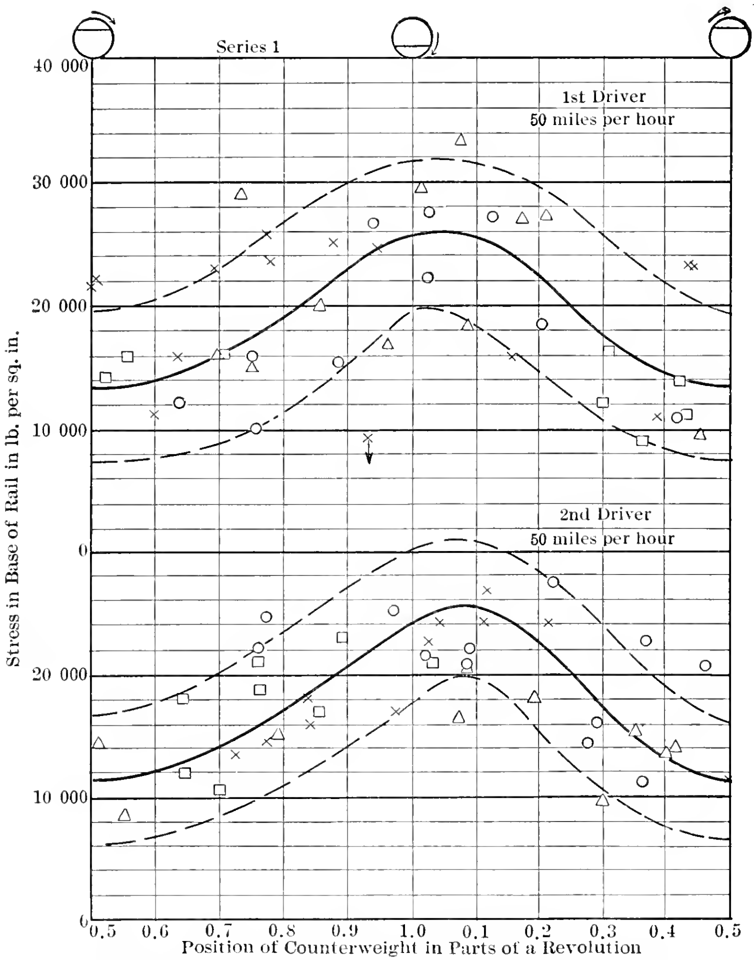


FIG. 10.—OBSERVED VALUES OF STRESS IN RAIL WITH SANTA FÉ TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

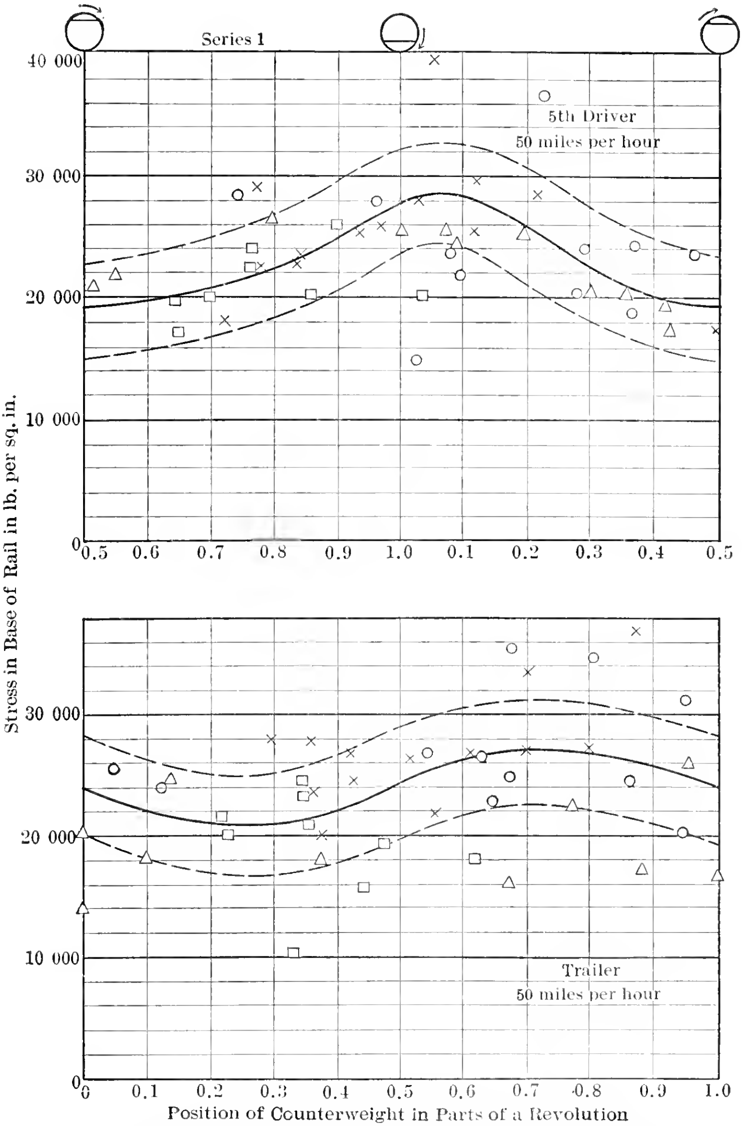


FIG. 11.—OBSERVED VALUES OF STRESS IN RAIL WITH SANTA FÉ TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

higher speed a noticeable variation exists, the high point of the curve occurring some time after the counterweights of the drivers have passed their high position.

In Table 5 are given the numerical values of the stress in rail under the several wheels as shown in Fig. 13. The mean values given are the mean values taken from the curves of Fig. 12 for an entire revolution.

In Table 6 are given ratios calculated from the data of Table 5. S_5 is the average stress in rail at 5 miles per hour. S_{25}, S_{40}, and S_{50} are the stresses in rail at the high point of curve for 25, 40, and 50 miles per hour, respectively. S_m is the stress found by taking the mean

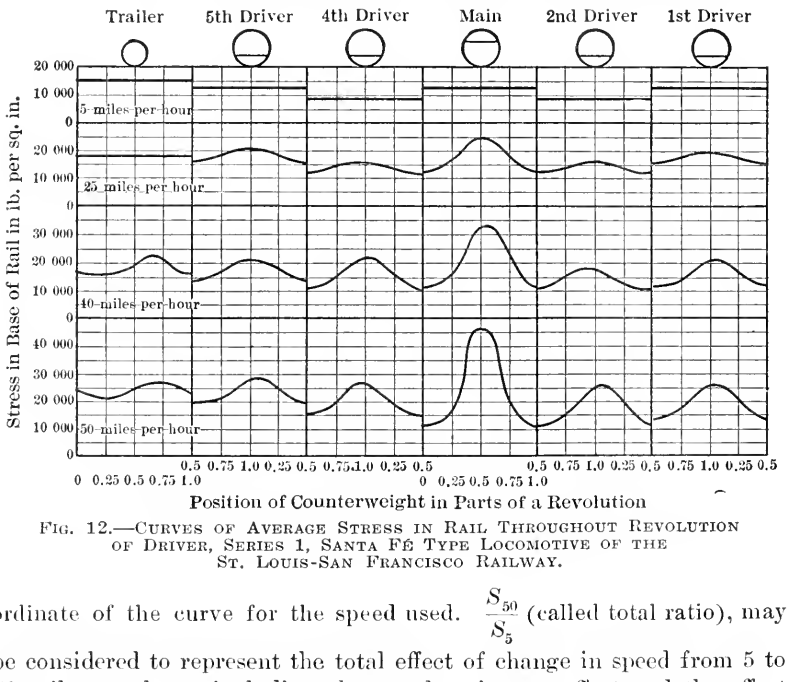


FIG. 12.—CURVES OF AVERAGE STRESS IN RAIL THROUGHOUT REVOLUTION OF DRIVER, SERIES 1, SANTA FÉ TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

ordinate of the curve for the speed used. $\frac{S_{50}}{S_5}$ (called total ratio), may be considered to represent the total effect of change in speed from 5 to 50 miles per hour, including the speed or impact effect and the effect of counterbalance. $\frac{S_m}{S_5}$ (the speed effect ratio) may be considered to represent the effect of speed as distinguished from effect of counterbalance. $\frac{S_{50} - S_m}{S_5}$ (the counterbalance effect) may be considered to represent the effect (increase or decrease) which may be attributed to counterbalance. The division into speed effect and counterbalance effect in this way is quite imperfect, but may be of service in helping to judge of these two effects.

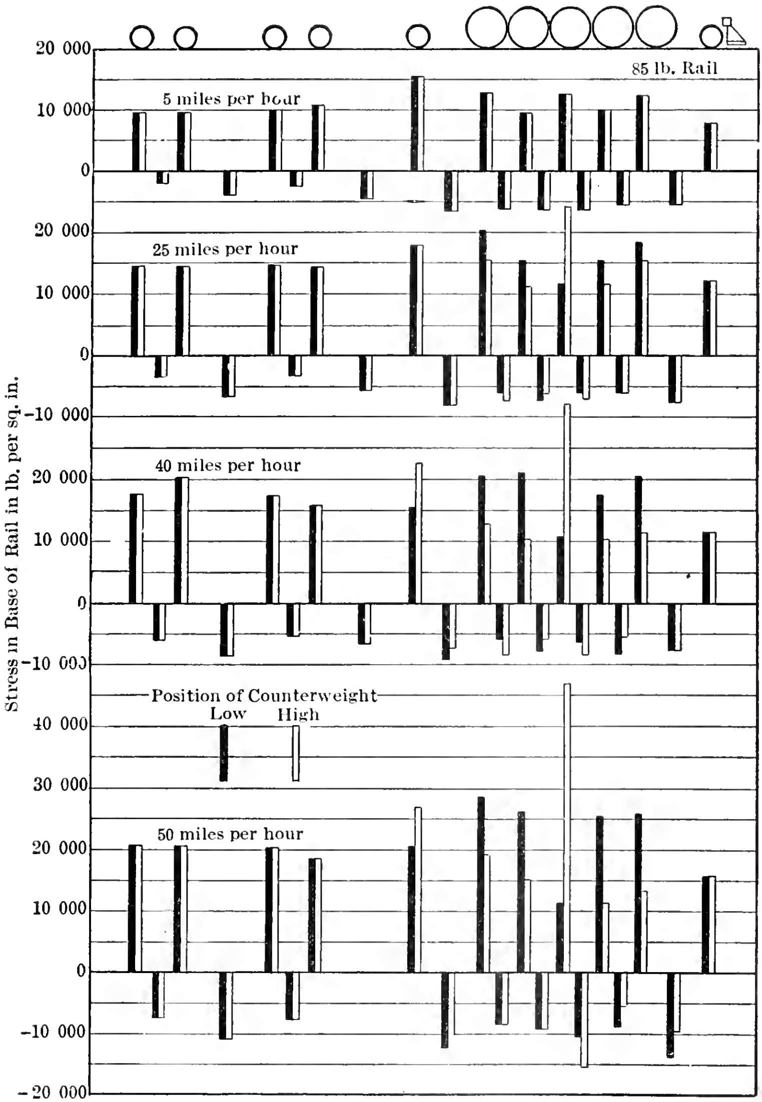


FIG. 13.—STRESS IN RAIL AT HIGH AND LOW POSITION OF COUNTERWEIGHT, SERIES 1, SANTA FÉ TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

TABLE 5.—STRESSES IN RAIL WITH SANTA FE TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY—MAXIMUM, MINIMUM, AND MEAN VALUES FROM CURVES FOR SERIES 1.

Stresses are given in pounds per square inch at base of rail.

Speed, in miles per hour.	Position of counter-weight.	Trailer.	Driver Number.					Front truck wheel.
			5		Main.		1	
5	Mean value...	15 200	12 700	9 600	12 500	9 800	12 500	7 900
25	Up..........	....	15 600	11 400	24 500	12 000	15 600	
	Down........	....	20 300	15 600	12 000	15 600	18 700	
	Mean value...	18 000	17 700	14 300	17 300	13 500	17 300	11 900
40	Up..........	22 400	13 000	10 400	32 200	10 400	11 500	
	Down........	15 600	20 800	21 300	10 900	17 700	20 800	
	Mean value...	18 000	17 200	16 100	18 700	13 500	15 300	11 400
50	Up..........	27 000	19 300	15 100	46 800	11 400	13 500	
	Down........	20 800	28 600	26 500	11 400	25 500	26 000	
	Mean value...	23 900	23 100	18 900	23 900	17 900	19 100	15 600
Calculated additional stress due to counter-balance at 50 miles per hour.............		600	8 100	11 400	24 200	11 300	8 100	700

Ratios for calculated effect of counterbalance in producing stress in rail are also given in Table 6. These were obtained by dividing the calculated resulting upward or downward pressure effect due to the dynamic augment of the rotating parts at the given speed by the static load pressure, the effect of all adjacent wheels upon moment and stress being considered in determining both static effect and counterbalance effect, as has already been referred to in the Article 4, "The Problem of Counterbalancing the Locomotive". To make clearer the method of calculation used in determining the calculated counterbalance ratio, as affecting the moments and stresses in rail, the following examples may be cited.

A reference to the principles given in the analysis of track action in the first progress report (pages 1203 to 1215) will show that the moment and therefore the stress produced by a combination of wheel loads may be found by calculating the load for a single wheel which is equivalent to the combined effect of the several wheels in moment-producing effect, and using the resulting load (which will be termed the equivalent single wheel load) in the formula for bending moment in the rail. This formula for bending moment in rail then is $M_0 = 0.318\ Px_1$ (Equation (8), p. 1205 of the first progress report), where P is the equivalent single wheel load and x_1 is the distance from wheel load to point of zero bending moment in rail for a single wheel load on the track in question.

The calculation of the equivalent single wheel load may then be made by adding algebraically to the load on the wheel itself the effect of the

TABLE 6.—RATIOS OF MAXIMUM STRESS, MEAN STRESS, AND ADDITIONAL STRESS TO STRESS AT 5 MILES PER HOUR, SANTA FE TYPE LOCOMOTIVE, SERIES 1.

Position of counterweight.	Trailer.		Driver Number.										Truck Wheel.	
			5		4		Main.		2		1			
	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.
Average stress at 5 miles per hour, as basis of comparison.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
25 Miles per Hour.														
Total effect.................. $\frac{S_{25}}{S_5}$	1.18	1.18	1.23	1.60	1.20	1.63	1.96	0.96	1.22	1.60	1.25	1.54	1.50	1.50
Effect of speed.............. $\frac{S_m}{S_5}$	1.18	1.18	1.42	1.42	1.50	1.50	1.38	1.38	1.38	1.38	1.38	1.38		
Effect of counterbalance (increase or decrease). $\frac{S_{25}-S_m}{S_5}$	0	0	− 0.19	+ 0.18	− 0.30	+ 0.13	+ 0.58	− 0.42	− 0.16	+ 0.22	− 0.13	+ 0.16		
Calculated effect of counterbalance..........................	+ 0.01	− 0.01	− 0.13	+ 0.13	− 0.23	+ 0.23	+ 0.43	− 0.43	− 0.25	+ 0.25	− 0.12	+ 0.12	+ 0.02	− 0.02
40 Miles per Hour.														
Total effect.................. S_{40}	1.47	1.03	1.03	1.64	1.09	2.23	2.58	0.88	1.06	1.81	0.92	1.67	1.45	1.45
Effect of speed.............. $\frac{S_m}{S_5}$	1.18	1.18	1.33	1.33	1.69	1.69	1.54	1.54	1.38	1.38	1.23	1.23		
Effect of counterbalance (increase or decrease). $\frac{S_{40}-S_m}{S_5}$	+ 0.29	− 0.15	− 0.30	+ 0.31	− 0.60	+ 0.54	+ 1.04	− 0.66	− 0.32	+ 0.43	− 0.31	+ 0.41		
Calculated effect of counterbalance..........................	+ 0.02	− 0.02	− 0.33	+ 0.33	− 0.59	+ 0.59	+ 1.10	− 1.10	− 0.65	+ 0.65	− 0.31	+ 0.31	+ 0.05	− 0.05
50 Miles per Hour.														
Total effect.................. $\frac{S_{50}}{S_5}$	1.78	1.38	1.52	2.25	1.58	2.77	3.75	0.92	1.17	2.60	1.08	2.08	1.97	1.97
Effect of speed.............. $\frac{S_m}{S_5}$	1.58	1.58	1.82	1.82	1.98	1.98	1.92	1.92	1.83	1.83	1.53	1.53		
Effect of counterbalance (increase or decrease). $\frac{S_{50}-S_m}{S_5}$	+ 0.20	− 0.20	− 0.30	+ 0.43	− 0.40	+ 0.79	+ 1.83	− 1.00	− 0.66	+ 0.77	− 0.45	+ 0.55		
Calculated effect of counterbalance..........................	+ 0.03	− 0.03	− 0.51	+ 0.51	− 0.91	+ 0.91	+ 1.74	− 1.74	− 1.01	+ 1.01	− 0.48	+ 0.48	+ 0.08	− 0.08

adjoining wheels, much as was done by means of ratios on page 1210 of the first progress report, since the combined effect is the algebraic sum of the effects of the individual wheel loads. Thus, for the Santa Fe type locomotive, the equivalent single wheel load for finding moments and stresses under the main driver for static loading by this method would be found as follows, using $x_1 = 29.3$ in., and taking values of coefficients corresponding to the effect at various distances found on the master diagram for bending moments given in Fig. 5, page 1207 of the first progress report:

Main driver load.			+ 31 600
Effect of first driver	$\frac{x}{x_1} = 4.30$	29 500 × (— 0.03) —	900
Effect of second driver	$\frac{x}{x_1} = 2.15$	28 100 × (— 0.21) —	5 900
Effect of fourth driver	$\frac{x}{x_1} = 2.15$	29 600 × (— 0.21) —	6 200
Effect of fifth driver	$\frac{x}{x_1} = 4.30$	29 200 × (— 0.03) —	900
Equivalent single wheel load at position of main driver. . .			+ 17 700

The equivalent additional single wheel load (positive or negative) due to counterbalance for a speed of 50 miles per hour, for use in calculating the additional stress in rail due to counterbalance, would be found as follows. For the counterbalance used in the calculations the upward and downward pressures at 50 miles per hour, the dynamic augments of the rotating parts, were calculated to be + 12 300, + 12 400, — 24 900, + 12 400, and + 12 300 lb. for the first, second, third, fourth, and fifth drivers, respectively. The equivalent additional single wheel load at the main driver, which may be attributed to the counterbalance will first be calculated for the counterweight up. For this position underbalance is counted as positive, since it produces additional downward pressure when the counterweight is up, and overbalance on the adjacent driver is counted as negative since it increases the pressure on that wheel and thus lightens the effect at the wheel under consideration. The values of the factors used are taken from Fig. 5 of the first progress report.

Dynamic augment of main driver.		+ 24 900
Effect of dynamic augment of first driver. . .	12 300 × 0.03	+ 400
Effect of dynamic augment of second driver.	12 400 × 0.21	+ 2 600
Effect of dynamic augment of fourth driver.	12 400 × 0.21	+ 2 600
Effect of dynamic augment of fifth driver. . .	12 300 × 0.03	+ 400
Equivalent additional single wheel load at position of main driver		+ 30 900
Equivalent static wheel load.		+ 17 700
Total equivalent single wheel load at 50 miles per hour. . . .		+ 48 600

Hence the following ratio is obtained:

$$\frac{\text{Equivalent additional single wheel load at 50 m. p. h.}}{\text{Equivalent static single wheel load}} = \frac{30\ 900}{17\ 700} = 1.74$$

This ratio represents the moment-making effect of the counterbalance expressed in terms of the moment-making load under static conditions; it may be considered that the stress in rail will increase as this ratio if the assumptions involved in the analysis are not modified by other features.

For counterweight down the effects of the counterbalance for the wheels adjoining the main driver will each be negative instead of positive, and the total equivalent static wheel load is $-30\ 900 + 17\ 700 = -13\ 200$. The ratio for the counterweight down then is $-\dfrac{30\ 700}{17\ 700} = -1.74$. The negative moment in rail here indicated should not be taken to mean that there is negative pressure or no pressure on the rail at the main driver, or that the rail is not depressed; the pressure of the main driver on the rail by the analysis used would be 6 700 lb. for the assumed condition. The rail depression would be that due to a single wheel load of 13 500 lb.

For the fourth driver the calculations for static load are:

Fourth driver load			$+$ 29 600
Effect of second driver	$\frac{x}{x_1} = 4.30$	$28\ 100 \times (-0.03)$	$-$ 800
Effect of main driver	$\frac{x}{x_1} = 2.15$	$31\ 600 \times 0.21$	$-$ 6 600
Effect of fifth driver	$\frac{x}{x_1} = 2.15$	$29\ 200 \times 0.21$	$-$ 6 100
Equivalent single wheel load at position of fourth driver			$+$ 16 100

The equivalent additional single wheel load at the fourth driver, which may be attributed to counterbalance, for counterweight up, is found as follows:

Dynamic augment of fourth driver		$-$ 12 400
Effect of dynamic augment of second driver	$-12\ 400 \times (-0.03)$	$+$ 400
Effect of dynamic augment of main driver	$24\ 900 \times (-0.21)$	$-$ 5 200
Effect of dynamic augment of fifth driver	$-12\ 300 \times (-0.21)$	$+$ 2 600
Equivalent additional single wheel load at position of fourth driver		$-$ 14 600
Equivalent static wheel load		$+$ 16 100
Total equivalent single wheel load at 50 miles per hour		$+$ 1 500

The ratio of equivalent additional single wheel load at 50 miles per hour to equivalent static single wheel load (calculated counterbalance ratio) then is $-\frac{14\,600}{16\,100} = -0.91$.

For counterweight down the total equivalent single wheel load becomes $+30\,700$ and the counterbalance ratio $+0.91$.

Values of the calculated effect of counterbalance, obtained by the method described, are given in Table 6 for all the drivers and the trailer and for three speeds. The values in effect give the ratio of the calculated stress in rail due to counterbalance to the stress in rail due to static loading.

The calculated stress in rail due to static loading and to counterbalance may be found of course by applying the equivalent single wheel load obtained as above in Equation (8) of the first progress report giving the bending moment in rail, $M_0 = 0.318\ P\ x_1$, and substituting the value of the section modulus of the rail used. Values so computed are given in the tables.

The data of the tests given in the figures and tables for the Santa Fe type locomotive show considerable variations in stress with changes in speed. For the position of counterweight which gives maximum effect (counterweight up for the main driver and counterweight down for the other drivers) there is a material increase in stress with increase in speed, particularly at the main driver where the stress at 50 miles per hour is 46 800 lb. per sq. in.; a ratio of 3.75 to the stress found at 5 miles per hour. For the opposite position of counterweight the change in stress with increase in speed is generally small, with several cases of decrease in stress.

The ratios given in Table 6 permit some comparison to be made on the effect of speed and of counterbalance taken separately, though, as has been stated, the method of separation is somewhat crude. By this method of separation, the effect of speed alone at 50 miles per hour is to give an additional stress in rail above the stress at a speed of 5 miles per hour which varies from 53 to 98 per cent. The main driver shows the greatest increase due to speed. The increase in stress due to counterbalance for the position which gives maximum effect does not vary greatly from the ratios for calculated effect of counterbalance; for some drivers it is more and for others less. For the main driver the increase in stress at 50 miles per hour, due to speed alone, is 92% of the stress found at 5 miles per hour. For the opposite position of counterweight the stress is generally greater than that which would be expected from calculations of counterbalance effect. It is to be expected that the results will show irregularities and that variations will occur. The deflection of the locomotive springs and the depression of track will change in amount at each wheel with the changing pressure as the position of counterweight changes, and these changes will

influence the pressures in the rail. Such changes may be relatively large at the main driver and adjoining drivers since the lack of balance for adjoining drivers is in opposite directions. The effect of the equalizing levers in transferring load to adjoining wheels complicates the situation and may account for some variations in stress.

For a speed of 40 miles per hour, relations similar to those found at 50 miles per hour exist. The stress found under the main driver is 2.58 times that at a speed of 5 miles per hour and the counterbalance effect itself results in doubling the stress in rail. At 25 miles per hour, the combined effect of speed and counterbalance nearly doubles the stress under the main driver, 58% of this increase apparently being attributable to effect of counterbalance. The ratios for speed and for counterbalance effect at this speed are similar to those found for 50 miles per hour.

It may be noted that had the readings on the right side of the locomotive only been used in this comparison the stresses at the several speeds would have been lower and the ratios in Table 6 would have been higher. Considering the uncertainty concerning the weights of the rotating parts and especially that concerning their exact distribution among the several drivers, it cannot be expected that a closer comparison may be made. The effect of speed at 50 miles per hour is to give an increase in rail stresses, ranging from 50 to 100%, and the effect of counterbalance in producing increased stress is close to that obtained by the method of calculation used.

The calculation for effect of counterbalance at the main driver given on page 36 indicates that when the counterweight is down, the combined effect of driver loads and counterbalance effect would produce a negative moment in the rail at the main driver, and this negative moment might be expected if the effect of speed did not itself contribute to a positive moment at the wheel. This effect of speed is so large that in all the tests the stress at the main driver with counterweight down indicates the presence always of a positive bending moment. The foregoing relates to stress and bending moment—the calculated rail pressure and rail depression have to be treated separately from stress and moment; even without the effect of speed there is no indication from the calculations given that the wheel would leave the rail.

Attention is called to the variation in stress at the trailer for the higher speeds. There is an appreciable change in stress as the counterweights of the drivers change position. The maximum stress occurs somewhat after the counterweight has reached its high position. Due to the large load on the trailer, its distance from other wheels, and the effect of counterbalance, the stress at this wheel is high, the highest of any except that at the main driver and except for the fifth driver at 5 miles per hour. The data of Series 2 will be found to give similar results. The time at which the maximum stress is found ranges from

the counterweight at six-tenths of a revolution after the counterweight is down to eight-tenths of a revolution; it occurs, therefore, between the positions of counterweight which give the minimum and the maximum stress at the driver ahead of the trailer.

It will be remembered that the values of stresses in rail considered in the foregoing discussion were taken from the curves of averages and that the band which enclosed the greater number of the observations extends 3 000 or 5 000 lb. per sq. in. above the curve and a similar distance below it. Above and below this band are other observed points, and the average of these outlying points is still 3 000 lb. per sq. in. above and below the limit of the bands. It may be expected that values may frequently be developed which are 3 000 or 5 000 lb. per sq. in. higher or lower than those used in the discussion and that not infrequently values of 3 000 lb. per sq. in. still greater or less will be found. Values 6 000 to 8 000 lb. per sq. in. greater than the stresses given in the discussion therefore may be expected not infrequently.

11.—The Santa Fe Type Locomotive; Rotating Parts Lightened.—In an effort to reduce the injurious effect of the Santa Fe type locomotives upon the track, the Railroad Company lightened certain of the rotating and reciprocating parts of locomotive No. 19 by cutting away metal at various places. A series of runs were made with this locomotive (Series 2) and comparisons will be made with the results of Series 1 which have been described in the preceding article. In making a comparison it should be borne in mind that the results found with two locomotives of nominally the same construction may differ considerably. The tests of Series 1, with locomotives as received from the builders, were made with two locomotives, Nos. 22 and 28. The tests of Series 2 were made at the same place in the track, with the instruments distributed in the same way, and the conditions of the test were much the same. The readings from the instrument on the left rail were included in the data used, as was the case for Series 1.

The statement from the office of the General Superintendent of Motive Power shows reductions in weight of rotating parts as follows: back end of main rod (considered to be tributary to the main driver in calculating its dynamic augment), 42 lb.; front end of side rod (tributary to first driver), no change; front intermediate side rod (tributary to second driver), 20 lb.; middle connecting side rod (tributary to main driver), 75 lb.; back intermediate side rod (tributary to fourth driver), 20 lb.; back end side rod (tributary to fifth driver), no change. Eighty-six pounds of metal were taken from the piston; 52 lb. from the cross-head, and 34 lb. from the front end of the main rod, but whatever the effect of the lightening of these reciprocating parts on the locomotive itself and on the effect of speed upon the track, this reduction does not alter the effect of rotating parts.

In computing the effect of counterbalance for Locomotive No. 19, the weights of rotating parts given in Table 1, page 15, were reduced by the amounts given above. The equivalent counterbalance at the pin of the main driver is 629 lb. instead of 746 lb. and that of the second and fourth driver 390 instead of 370 lb. It will be seen that the underbalance of the main driver is decreased and the overbalance (for rotating parts) of the other two drivers named is increased, the first and fifth drivers not having any change. The effect of the increase of overbalance of the second and fourth drivers upon the stress under these two drivers is nearly neutralized by the influence of the decrease in underbalance of the main driver, and calculations indicate that the resulting effect at the second and fourth drivers is negligible. The cal-

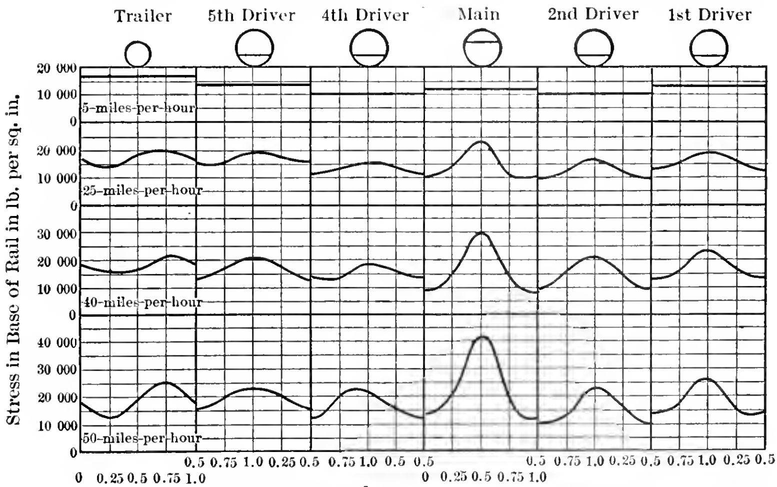


FIG. 14.—CURVES OF AVERAGE STRESS IN RAIL THROUGHOUT REVOLUTION OF DRIVER, SERIES 2, SANTA FÉ TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

culated effect at the main driver however will be to decrease the stress in rail due to dynamic augment about 11 per cent. The calculated decrease in stress in rail at the main driver for these conditions would be 1 800 lb. per sq. in. at 40 miles per hour and 2 800 lb. per sq. in. at 50 miles per hour.

Fig. 14 gives the stress in base of rail throughout a revolution of driver for all the drivers and the trailer for Series 2, obtained in the same way as were those already given for Series 1, and Fig. 15 gives the value of the stresses in base of rail at the various wheels for the high point and the low point of these stress curves. Table 7 gives numerical values of these stresses, as well as the values of the mean stress for the several stress curves. In Table 8 are given ratios which

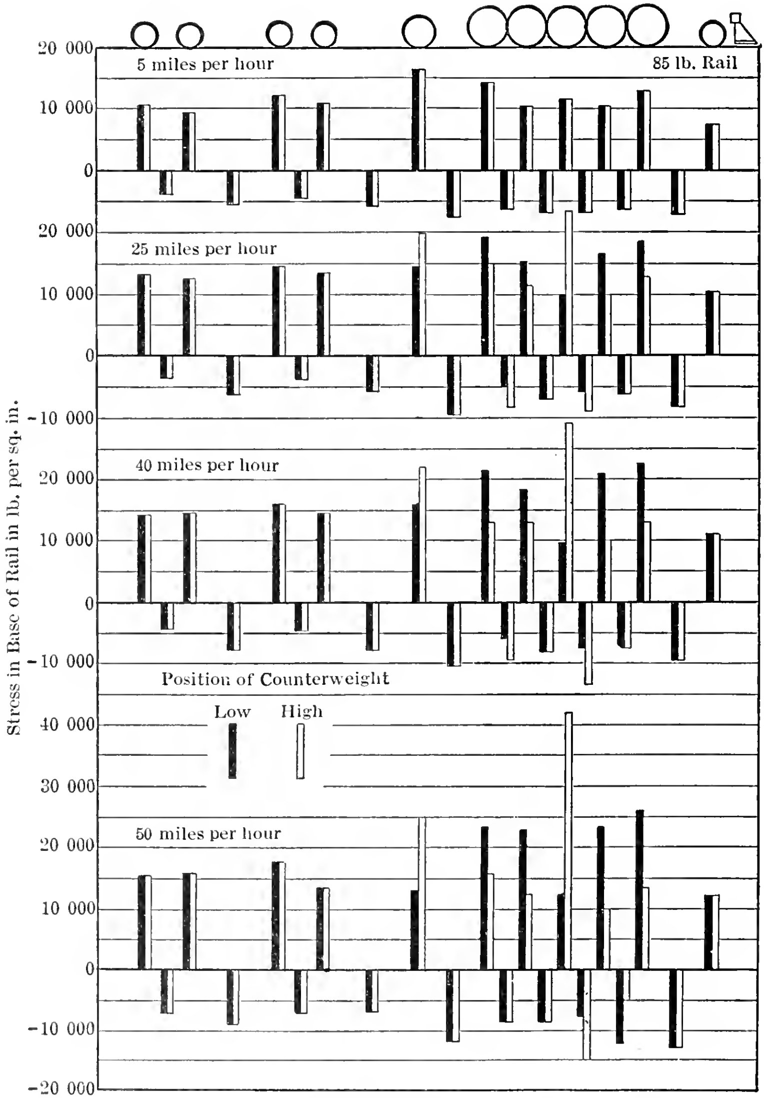


FIG. 15.—STRESS IN RAIL AT HIGH AND LOW POSITION OF COUNTERWEIGHT, SERIES 2, SANTA FÉ TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

TABLE 7.—STRESSES IN RAIL WITH SANTA FE TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY—MAXIMUM, MINIMUM, AND MEAN VALUES FROM CURVES FOR SERIES 2, PARTS LIGHTENED.

Stresses are given in pounds per square inch at base of rail.

Speed, in miles per hour.	Position of counter-weight.	Trailer.	Driver Number.					Front truck wheel.
			5	4	Main.	2	1	
5	Mean value..	16 300	14 400	10 400	11 400	10 400	13 000	7 600
25	Up...........	19 800	14 900	11 400	23 400	10 000	13 000	
	Down........	14 600	19 200	15 100	9 400	16 600	18 700	
	Mean value..	16 300	16 800	13 400	14 600	12 800	15 800	10 200
40	Up...........	21 800	13 000	13 000	29 100	10 000	13 000	
	Down........	15 600	21 300	18 200	9 400	20 800	23 400	
	Mean value..	17 800	17 500	15 500	17 100	15 100	17 200	10 800
50	Up...........	25 000	15 600	12 500	42 000	10 000	13 500	
	Down........	13 000	23 400	22 900	12 500	23 400	26 000	
	Mean value..	18 500	20 200	17 500	23 900	15 400	18 200	12 200
Calculated additional stress due to counter-balance at 50 miles per hour.............		600	7 900	11 300	21 100	11 200	7 900	700

may be considered to express the effect of speed and the effect of counterbalance. These correspond to the ratios given in Table 6. Ratios expressing the calculated relative effect of counterbalance are also given.

Comparisons of the two series to determine effect of counterbalance have less value because the locomotives used in the two series give somewhat different speed effects and different distributions of stress under the several drivers, the increase in mean stress over that at 5 miles per hour being generally smaller in Series 2 than in Series 1. The advantage obtained through lightening the rotating parts may be shown by comparing the stress at the main driver with the average of the stresses at the adjacent drivers, taking into account also the differences in stress which exist at 5 miles per hour for the two series, differences which may be due to a different distribution of load among the drivers in the locomotives. For both counterweight up and counterweight down the difference between the stress at the main driver and the average of the stresses at the adjacent drivers is substantially less for Locomotive No. 19 than for the other two locomotives; this is true at speeds of 40 and 50 miles per hour to an amount beyond the difference in stress at these drivers for 5 miles per hour.

The effect of the lightening of rotating parts is seen also by comparing the differences between maximum stress and mean stress for the main driver and adjoining drivers for Series 1 and 2 (Tables 5 and 7); the effect of counterbalance is less for the main driver in Series 2 than in Series 1 as compared with the change for the average of the two adja-

TABLE 8.—RATIOS OF MAXIMUM STRESS, MEAN STRESS, AND ADDITIONAL STRESS TO STRESS AT 5 MILES PER HOUR, SANTA FE TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY, SERIES 2, PARTS LIGHTENED.

Position of counterweight.	Trailer.		Driver Number.										Truck wheel.	
			5		4		Main.		2		1			
	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.
Average stress at 5 miles per hour assumed as basis of comparison..	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
25 Miles per Hour.														
Total effect.................... $\frac{S_{25}}{S_5}$	1.21	0.89	1.04	1.34	1.10	1.45	2.04	0.82	0.95	1.60	1.00	1.44	1.34	1.31
Effect of speed...... .... $\frac{S_m}{S_5}$	1.00	1.00	1.17	1.17	1.29	1.29	1.27	1.27	1.23	1.23	1.22	1.22		
Effect of counterbalance (increase or decrease)... $\frac{S_{25} - S_m}{S_5}$	+ 0.21	− 0.11	− 0.13	+ 0.17	− 0.19	+ 0.16	+ 0.77	− 0.45	− 0.28	+ 0.37	− 0.22	+ 0.22		
Calculated effect of counterbalance.	+ 0.01	− 0.01	− 0.12	+ 0.12	− 0.23	+ 0.23	+ 0.38	− 0.38	− 0.25	+ 0.25	0.12	+ 0.12	+ 0.02	0.02
40 Miles per Hour.														
Total effect.................... $\frac{S_{40}}{S_5}$	1.34	0.96	0.91	1.49	1.25	1.75	2.55	0.82	0.95	2.00	1.00	1.80	1.43	1.43
Effect of speed................. $\frac{S_m}{S_5}$	1.09	1.09	1.22	1.22	1.49	1.49	1.49	1.49	1.45	1.45	1.32	1.32		
Effect of counterbalance (increase or decrease).. $\frac{S_{40} - S_m}{S_5}$	+ 0.25	− 0.13	− 0.31	+ 0.27	− 0.24	+ 0.26	+ 1.06	− 0.67	− 0.50	+ 0.55	0.32	+ 0.48		
Calculated effect of counterbalance.	+ 0.02	− 0.02	− 0.32	+ 0.32	− 0.58	+ 0.58	+ 0.97	− 0.97	− 0.64	+ 0.64	0.30	+ 0.30	+ 0.05	− 0.05
50 Miles per Hour.														
Total effect.................... $\frac{S_{50}}{S_5}$	1.53	0.79	1.09	1.63	1.20	2.20	3.68	1.09	0.95	2.25	1.04	2.00	1.61	1.61
Effect of speed.................. $\frac{S_m}{S_5}$	1.13	1.13	1.41	1.41	1.68	1.68	2.09	2.09	1.48	1.48	1.40	1.40		
Effect of counterbalance (increase or decrease).. $\frac{S_{50} - S_m}{S_5}$	+ 0.40	− 0.31	− 0.32	+ 0.22	− 0.48	+ 0.52	+ 1.59	− 1.00	− 0.53	+ 0.77	0.36	+ 0.60		
Calculated effect of counterbalance.	+ 0.03	− 0.03	− 0.50	+ 0.50	− 0.90	+ 0.90	+ 1.52	− 1.52	− 1.00	+ 1.00	0.47	+ 0.47	+ 0.08	− 0.08

cent drivers. It seems probable that the lower average increase in stress due to speed in Series 2 may also be due, in part, to the lightening of parts.

A marked difference in the two series, however, lies in the greater effect of speed and counterbalance for 50 miles per hour found in Series 1 as compared with Series 2. Much of this difference is in speed effect alone. If the stresses at drivers and trailer be summed for the two series it will be seen that for 50 miles per hour the sums of maximum stress, minimum stress, mean stress, stress with counterweight up, and stress with counterweight down will each be about 10% of the mean stress more for Series 1 than for Series 2, while for 25 and 40 miles per hour there is relatively little difference. The same effect may be seen by comparing the ratios of Tables 6 and 8.

As has already been stated, in Series 1 Locomotive No. 22 was used in the runs at 5 and 40 miles per hour and part of the runs at 25 miles per hour, and Locomotive No. 28 was used in the remaining runs at 25 miles per hour and in all the runs at 50 miles per hour. The results for the tests at 25 miles per hour have not been separated for the two locomotives used in Series 1. The results show that locomotives of the same nominal construction may have quite different distribution of loads among the drivers.

The stresses in rail for the locomotive with rotating parts lightened are still very high at speeds of 25 miles per hour or more.

12.—Comparison of Stress Under the Two Sides of the Santa Fe Type Locomotive.—The experience of the St. Louis-San Francisco Railway with these Santa Fe type locomotives gave some indication that injuries were more common or greater in the rail at the left side of the locomotive than in the other rail. To learn whether the stresses in rail were the same under the two sides of the locomotive, tests were made with Locomotive No. 22. The four instruments were placed on one rail as shown in Fig. 4, and runs were made in one direction at speeds of 5, 25, and 40 miles per hour, forming Series 3, the instruments being on the rail at right side of locomotive. The locomotive was then reversed in direction and runs over the same track were made in this direction at the same speeds, forming Series 4 for instruments on rail at left side of locomotive. The instruments retaining their position on the same rail and other conditions remaining the same, and all the tests being made on one day, results were thus obtained for the effect of the two sides of the locomotive which seem comparable.

The data were reduced in the usual way and plotted according to position of counterweight, and the maximum value of the stress curve for each wheel at each speed was determined. It was found that the stress in rail under the left side of this locomotive was considerably greater than that under the right side. That this difference is not

caused by speed or counterbalance is indicated by a marked difference at a speed of 5 miles per hour; the sum of the stresses in rail at the five drivers, trailer, and truck wheel, as found for the left side of the locomotive, is as much as 20% greater than the sum of the corresponding stresses for the right side of the locomotive. A similar difference is found at all speeds, both for mean stresses and for maximum stresses. It seems that the difference is due to a cause not related to speed.

That this excess of stress at one side of the locomotive was not due to methods of testing is shown by the stresses at the wheels under the tender. The average stress for the three speeds for Series 3 (rail at right side of locomotive) is 15 500 lb. per sq. in. and for Series 4 (rail at left side of locomotive) is 15 300 lb. per sq. in. A few runs of Series 3 were made before the noon hour; the remaining runs and all of Series 4 were made after the noon hour. There would be some decrease in the load of coal and water, but this would not be large.

In all the other tests with the Santa Fe type locomotive, one instrument was placed on the rail at the left side of the locomotive opposite the middle one of the three instruments on the rail at the right side, as shown in Fig. 4. In the plots of data, it was found that the results obtained with the instrument at the left side generally average higher than the results obtained with the other instruments, thus agreeing in this respect with the series just discussed. Whatever the cause of this variation, it has made complications in the interpretation of the data for other purposes and has thrown uncertainty on some comparisons which it was desired to make, but the relatively small amount of data available has made it seem best generally to include all the instrumental results even with this added complication. The use of one instrument on the second rail has seemed advisable for the purpose of checking up in possible cases of irregular or unexpected values in the data.

The reason for this difference in stress developed on the two sides of the locomotive is not known; it is planned to make a further investigation of the conditions.

It should be noted that the lateral bending of rail due to nosing is not here discussed; it may have an important relation to rail injury.

13.—The Effect of Santa Fe Type Locomotive Upon Rail and Track. —The tests made with the locomotive of the Santa Fe type gave an interesting opportunity to find the effect upon rail stresses produced when the desired amount of counterweight is not or can not be placed on the main driver, but instead the deficiency for the given wheel is distributed among the other drivers which thereby have their counterweight increased above what is already an overbalance so far as rotating parts and vertical pressure are concerned. The increased stress in the rail is due not alone to the increased pressure on the rail given by the excess of weight of rotating parts on the main driver when the crank pin is

down, but it may be seen from the illustrative calculations given in Article 10 on "Effect of Speed and Counterbalance" that the overbalance in the adjacent drivers at the same time relieves part of the pressure on the rail at those drivers and the effect of this decrease in pressure is to increase the bending moment in the rail under the main driver.

Similarly, the addition of counterweight to drivers other than the main driver not only increases the counterweight effect in the rail at these drivers (which are already overbalanced so far as rotating parts are concerned), but the deficiency in the counterweight of the main driver decreases the pressure on the rail at the main driver when the counterweight is down and thus increases the moment in the rail at the adjacent drivers. The existence of these influences is evident from the analysis and illustrations already given. Whatever may be the effect of this abnormal distribution of counterweight upon the frame of the locomotive or upon its riding qualities, it is evident that a deviation from a uniformity of counterbalance effect among the several drivers aggravates conditions producing stresses in rail which otherwise may be bad enough.

The Santa Fe type locomotives used in the tests may seem extreme in the amount and distribution of counterweight, but the underbalance of the main driver in locomotives of this type as used on some railroads is reported to be considerably greater than found on these locomotives; on the other hand, the Santa Fe type locomotive of at least one railroad has an underbalance of less than half that of those on the St. Louis-San Francisco Railway. In other features of the design also these locomotives were not calculated to produce low or even stresses in the rail. The weight given for the main driver, 31 600 lb., is considerably greater than that on the second and fourth drivers, which might advantageously be given more load than the first and fifth. Even at low speeds the second and fourth drivers give considerably lower stresses than the others. Besides, the effect of the cylinder pressure at mid-stroke when the locomotive is working is to give a vertical component at crank pin which serves to increase the pressure on the rail under the main driver both for counterweight up and counterweight down. The weight on the trailer, a wheel located some distance from other wheels, and thus having little moment-decreasing influence from the other wheels in these locomotives, is too great to produce even effects in rail stresses, the stress in rail at this wheel at low speeds (see Table 5) being considerably greater than those at the drivers, and at higher speeds generally being the highest at any point except at the main driver.

The stresses in rail produced by these locomotives at speeds of 25 miles per hour are high. It should be borne in mind, too, that the values under discussion are the average stresses for the runs, and that the occa-

sional maximum stress is much higher, and that the stress at one side of the rail will be still higher. Speed and counterbalance was found to increase stresses very rapidly. For the main driver the ratios of the stresses at the higher speeds to the stress at 5 miles per hour (2.04 for 25 miles per hour, 2.54 for 40 miles per hour, and 3.68 for 50 miles per hour) show undesirable and unsatisfactory conditions in a locomotive in so far as the effect on the maintenance and life of the track is concerned. The occurrence of stresses in base of rail (the average of the values at the two edges) as high as 52 000 lb. per sq. in. (and 10% higher in head of rail), observed at high speeds in a number of cases where the records were well defined, shows that it is not strange that kinks and rail failures were produced in the regular service of these locomotives. In some of the runs at 50 miles per hour, kinks in rail were developed near the rail on which instruments were placed. Even at lower speeds than those which may have produced such visible injury to track, the punishment of the track and the effect of continued application of such stresses probably would be sufficient to cause considerable injury to the track structure. Such locomotives should run only at low speeds, and every precaution should be taken to prevent even the occasional use of higher speeds on heavy down grades in undulating country or through other carelessness. The observance of much higher stresses under the left side of the locomotive than under the right it is hoped will lead to investigation to determine the origin of this undesirable effect upon track.

14.—Tests with the Pacific Type Locomotive.—The main purpose of the tests with the Pacific type of passenger locomotive made on the St. Louis-San Francisco Railway was to find the increase in stress in rail due to speed and counterbalance. The Railroad Company, however, desired to learn the effect of certain variations in these locomotives,—the addition of a mechanical stoker, different arrangements of an equalizing lever, and the lightening of rotating parts—and the tests were outlined with a view of including the effect of these variations in the locomotives. Part of the changes in locomotive were relatively small and their extent had not been realized when the tests were started; the resulting change in distribution of load among the several wheels was also uncertain. The demands for locomotives under the existing traffic conditions and the beginning of winter weather made it impracticable to extend the tests to secure an adequate number of runs for some of the purposes of the test. In getting the effect of speed and counterbalance, it has been found best to group series of tests which have different locomotives and different conditions of locomotive, so that some of the effects may be masked by the differing conditions

and the real increases due to speed and counterbalance therefore may be greater than the values reported indicate.

Table 4 gives the variations in the Pacific type locomotives used. Series 8 to 12 were made with the locomotives as received from the builders except as the position of the pin in the equalizing lever was changed for some of the tests. The second location of test (rail adjoining that used for the first test) was used to determine whether the first test location was in any way abnormal; a comparison of the results indicate that there was little difference in conditions.

Series 5 and 6 made with Locomotive No. 1061 having a mechanical stoker added were made at the beginning of the test work on the St. Louis-San Francisco Railway. It is evident from the data that the instruments were not working satisfactorily or the observers were not in good practice. Many records were so indefinite as not to be usable. As the number of runs was small, the number of definite values obtained was too small to use in making comparisons, and these two series will not be reported. As the stoker weighed only 3 500 lb. and the weight added to one wheel was probably much less than 1 000 lb., a large number of runs would have been necessary to secure an adequate amount of data for making a proper comparison.

The Pacific type locomotives were received and generally used with the pin in the rear hole of the equalizer bar at the rear of the locomotive. The change of the pin to the middle hole releases weight from the trailer and increases the weight on the drivers. It is also expected to decrease the weight on the front trucks. The changes in the weights on the several wheels as calculated by the Mechanical Department of the railway may be seen from the following weights:

	Trailer.	Third driver.	Main driver.	First driver.	Two truck wheels.
Pin in rear hole	32 150	29 700	32 250	29 750	28 850
Pin in middle hole..	28 850	31 950	34 450	31 950	25 550

These calculated values indicate that by the change in length of equalizing bars, 3 300 lb. is released from the trailer and 3 300 lb. from the two truck wheels and that this 6 600 lb. is divided equally among the three drivers. Based on the calculated or assumed distribution of the weight of the locomotive among the several wheels, the stress in the rail calculated by the method of combination of wheel loads given in the first progress report would be decreased by 2 300 lb. per sq. in. under the trailer and 1 000 and 1 400 lb. per sq. in., respectively, under the two truck wheels, while the stresses under the three drivers would be increased by 1 800, 1 000 and 1 500 lb. per sq. in., respectively. The test results are not fully comparable for this purpose, and the results of the series with the pin in the two positions are not entirely concordant. The average of the results of the several series indicates that changing

the pin to the middle hole decreases the stress in rail under the trailer, and increases the stress under the three drivers, with little change under the truck wheels. The amount of this change, however, as given by the averages of Series 7 to 12, is much less than the change found by calculation on the basis of the assumed distributions of weight. The effect of speed was noticeably less at the trailer with the pin in the middle hole.

Series 9, 10, 11, and 12 may be grouped together for finding the effect of speed and counterbalance, though the differences in conditions for the four series make comparisons in some ways somewhat uncertain. As there were about the same number of observations for each position of pin in the equalizing bar, this variation should not affect the results materially. The effect of differences in locomotives and of differences in track in the two locations of course is not known, but it is thought to be not large.

The observed values of stresses in base of rail for each speed in each series were plotted with respect to position of counterweight, the values of the plotted points in groups for each twentieth of a revolution were then averaged and a curve drawn to represent as well as possible the position and trend of these points, as has already been described for the tests with the Santa Fe type locomotive. The data for each speed of the four series (9, 10, 11, and 12) were also plotted together and curves drawn which represent the averages of the four series. Fig. 16 gives the resulting curves for the combined series. The maximum, minimum, and mean values for the curves were taken from the diagrams. The values of the stress in rail for the four series and the combined series are given in Table 9. It should be noted that, as was the case in the tests with the Santa Fe type locomotive, the greater number of the plotted observed values was found in a belt on each side of the curve of averages in the diagrams of data, the limits of the belt being 3 000 to 5 000 lb. per sq. in. above and below the curves, while still other points were above and below the belt. Fig. 17 shows graphically the principal stresses of the combined four series, including the average negative stress at points between wheels.

In Table 10 are given the ratios calculated from the data of Table 9 for the combined four series. S_5, S_{45}, and S_{60} are the stresses in rail at speeds of 5, 45, and 60 miles per hour, respectively. S_m is the mean value of the stress curve for the speed used. The total ratio, speed effect ratio, and counterbalance ratio are used as in the discussion of the counterweight with the Santa Fe type locomotive. Calculated counterbalance ratios, obtained with the data of counterbalance given in Article 5 on "The Locomotives", by the method already used, are also given in the table. The calculated upward and downward pressures at 60 miles per hour are 12 800, 10 000, and 13 000 lb. for the first, second, and third drivers, respectively. The downward and upward pressures

TABLE 9.—STRESSES IN RAIL WITH PACIFIC TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY. MAXIMUM, MINIMUM, AND MEAN VALUES FROM CURVES FOR SERIES 9, 10, 11, AND 12.

Stresses are given in pounds per square inch at base of rail.

Speed, in miles per hour.	Position of counterweight.	Trailer.	Driver Number.			Truck Wheel.	
			3	Main.	1	2	1
			Series 9				
5	Mean value	20 300	16 200	15 200	15 400	6 000	9 000
45	Up	32 200	21 300	24 400	15 600		
	Down	23 500	27 600	14 600	25 000		
	Mean value	27 700	23 700	19 200	20 800	10 400	13 600
60	Up	33 300	14 100	26 000	15 600		
	Down	22 800	31 200	16 200	26 000		
	Mean value	27 400	21 800	22 200	20 300	12 400	16 000
			Series 10				
5	Mean value	20 800	17 000	15 800	14 100	5 200	8 900
45	Up	33 800	20 000	25 000	17 700		
	Down	29 700	27 600	19 300	24 000		
	Mean value	31 400	23 100	21 300	19 900	14 000	15 400
60	Up	34 800	17 000	24 800	14 100		
	Down	28 100	28 300	15 100	26 800		
	Mean value	80 300	21 900	18 900	19 300	14 700	16 200
			Series 11				
5	Mean value	22 200	17 600	18 000	15 200	5 800	8 600
45	Up	28 100	13 000	28 100	14 000		
	Down	23 400	24 400	14 000	21 300		
	Mean value	25 300	18 200	20 700	16 100	13 000	15 500
60	Up	36 400	18 200	36 400	16 600		
	Down	28 600	34 800	19 800	26 000		
	Mean value	32 100	25 800	25 400	19 700	14 000	18 700
			Series 12				
5	Mean value	23 900	17 200	15 600	14 800	5 600	9 800
45	Up	31 200	18 200	24 100	15 400		
	Down	20 800	29 100	15 600	23 900		
	Mean value	24 200	22 500	19 900	19 600	12 100	15 900
60	Up	......	19 800	28 600	14 800		
	Down	.....	37 000	20 600	23 900		
	Mean value	35 400	27 500	24 200	21 100	15 200	17 900
			Series 9, 10, 11, and 12—Combined				
5	Mean value	21 800	17 500	16 800	14 700	5 600	9 300
45	Up	31 200	19 800	25 000	15 100		
	Down	25 000	26 500	15 600	22 900		
	Mean value	27 900	21 900	20 200	19 200	12 500	15 100
60	Up	37 000	17 200	28 600	16 100		
	Down	29 600	32 800	17 200	26 000		
	Mean value	32 900	25 100	22 300	20 700	13 900	17 200
Calculated stress under static load		23 500	17 300	17 100	16 400	4 400	9 100
Calculated additional stress due to counter-balance at 60 miles per hour		700	8 700	4 400	8 500	2 100	100

TABLE 10.—RATIOS OF MAXIMUM STRESS, MEAN STRESS, AND ADDITIONAL STRESS TO STRESS AT 5 MILES PER HOUR, PACIFIC TYPE LOCOMOTIVE. SERIES 9, 10, 11 AND 12 COMBINED.

Position of counterweight.	TRAILER.		DRIVER NUMBER.						TRUCK WHEEL.			
			3		Main.		1		2		1	
	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.
Average stress at 5 miles per hour assumed as basis of comparison	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
45 MILES PER HOUR.												
Total effect $\frac{S_{45}}{S_5}$	1.43	1.15	1.13	1.52	1.48	0.93	1.03	1.56	2.21	2.21	1.63	1.63
Effect of speed $\frac{S_m}{S_5}$	1.28	1.28	1.26	1.26	1.20	1.20	1.31	1.31				
Effect of counterbalance (increase or decrease) $\frac{S_{45} - S_m}{S_5}$	+ 0.15	– 0.13	– 0.13	+ 0.26	+ 0.28	– 0.27	– 0.28	+ 0.25				
Calculated effect of counterbalance	+ 0.01	– 0.01	– 0.28	+ 0.28	0.15	+ 0.15	– 0.29	+ 0.29	+ 0.27	0.27	+ 0.01	– 0.01
60 MILES PER HOUR.												
Total effect $\frac{S_{60}}{S_5}$	1.69	1.36	0.98	1.88	1.70	1.24	1.10	1.77	2.18	2.48	1.85	1.85
Effect of speed $\frac{S_m}{S_5}$	1.50	1.50	1.14	1.41	1.32	1.32	1.41	1.41				
Effect of counterbalance (increase or decrease) $\frac{S_{60} - S_m}{S_5}$	+ 0.19	– 0.15	0.15	+ 0.41	+ 0.38	– 0.30	– 0.31	+ 0.36				
Calculated effect of counterbalance	+ 0.03	– 0.03	– 0.50	+ 0.50	– 0.26	+ 0.26	– 0.52	+ 0.52	+ 0.18	– 0.48	+ 0.01	– 0.01

were considered as positive and negative loads at the several drivers, and the additional equivalent single wheel load for this combination of added loads was calculated for each wheel by the method described in the case of the Santa Fe type locomotive. The ratios of the resulting values to the equivalent single wheel loads found for the combination of nominal static wheel loads was calculated, and is given as the calculated counterbalance ratio.

The ratios in Table 10 may be considered to separate the effect of counterbalance and the effect of speed alone, though it must not be expected that the division of effect will be accurate.

It is seen that the maximum stress in rail at the first and third driver occurs when the counterweight is down at speeds of both 45 and 60 miles per hour, while the maximum stress at the main driver

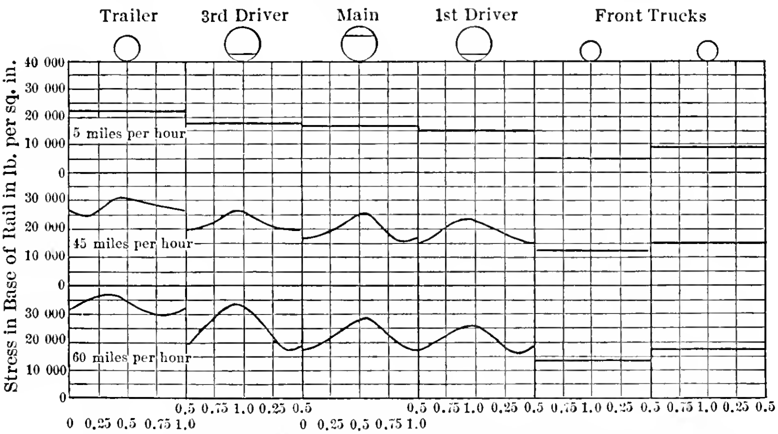


FIG. 16.—CURVES OF AVERAGE STRESS IN RAIL THROUGHOUT REVOLUTION OF DRIVER, SERIES 9, 10, 11, AND 12 COMBINED, PACIFIC TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

occurs when the counterweight is up. The maximum stress at the trailer occurs when the counterweight of the drivers is up, the exact position being when the drivers have turned about four-tenths of a revolution from the down position of the counterweight. The signs of the counterbalance ratio for the main driver given in Table 10, it is seen, are opposite to the signs of the observed counterbalance ratio for the main driver, while for the other wheels the signs of the calculated and the observed ratios agree.

No explanation is offered except that the weights of the rotating parts may be different from those given in Table 2, or that the assumed effect of such parts as the main rod is in error. The effect of the main rod and side rod being outside the plane of the driver seems to account for only part of the discrepancy. The results are so pronounced and

the information on the position of counterweight for the observations so definite and so general that no doubt can be thrown on the character of the test data in this respect. It may be added that it would not require a large discrepancy in the amount and position of the counterweight of the main driver, or in the weight of the rotating parts tributary to this driver, to produce quite a change in the calculated vertical pressure at the down position of the counterweight, taking into account the effect of the dynamic augment of the adjacent drivers upon the vertical pressure at the main driver. Possibly the weight of rotating parts given may not have been properly divided among the three drivers.

It will be noted that the counterbalance effect upon the trailer is considerably larger than would be expected from the effect due to relief of load on rail at third driver when the counterweight is up; it may receive a portion of the effect of counterbalance of the drivers in some way through the equalizing levers. The maximum stress at the trailer occurs when the counterweights of the drivers have moved about four-tenths of a revolution beyond their low position. It will be observed that the ratios for the counterbalance effect of the drivers is considerable, amounting to 44% of the low speed stress for the third driver at a speed of 60 miles per hour. The method of combining the results of the series may be expected to make the apparent effect of counterweight smaller than the actual effect, the tendency of the combination being to flatten out the curves; for example, Series 12 gives results which are considerably higher than those of Table 10. It seems probable that there is some transfer from main driver to adjacent drivers through the equalizer bars when the counterweight is up and *vice versa* when it is down.

The effect of speed alone, as shown by the speed effect ratios, is quite uniform for the drivers and trailer and is closely proportional to the speed. The additional stress due to speed alone is quite moderate for all three wheels. The stress at the truck wheels increases rapidly, though the value at 60 miles per hour is not excessive. Fig. 17 gives the stresses at the wheels of the tender for Series 9, 10, 11, and 12 combined. The effect of speed is considerable, the average ratio of stress at 45 and 60 miles per hour to the stress at 5 miles per hour being 1.95 and 2.25, respectively.

The total effect ratio indicates that the effect of speed and counterbalance together does not differ much for the several drivers and the trailer, either for maximum values or generally for minimum values. Attention is called to the very high stress at the trailer at all speeds and to the considerable increase with speed—this too in results which average the data with the equalizer pin in the two positions. The stress in the third driver was also high. It should be borne in mind, of course, that the band of the plotted data gave frequent points 4 000 lb.

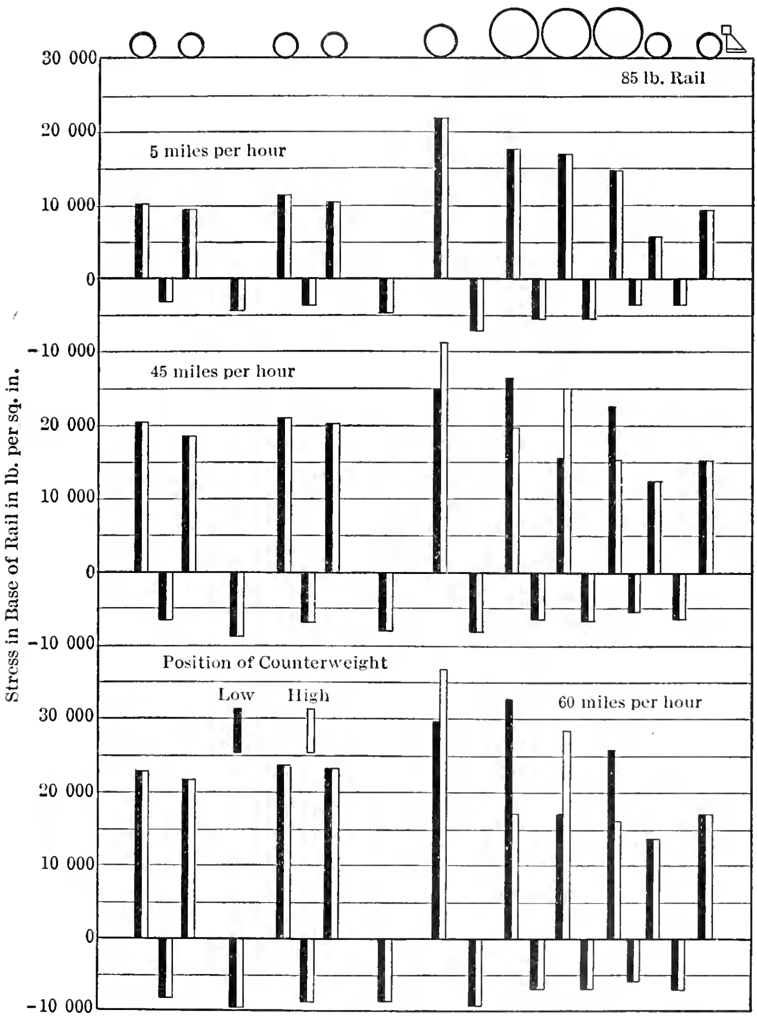


FIG. 17.—STRESS IN RAIL AT HIGH AND LOW POSITION OF COUNTERWEIGHT, SERIES 9, 10, 11, AND 12 COMBINED, PACIFIC TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

per sq. in. higher than these values and that occasional values were found which are more than 10 000 lb. per sq. in. higher.

The Railroad Company lightened somewhat some of the rotating and reciprocating parts of Locomotive No. 1063 by cutting away metal. The weight given for the lightening of the rotating parts included 9 lb. for the rear end of the main rod and 54 lb. for the part of the side rod considered to be tributary to the main driver. The information furnished is that no change was made in rotating parts affecting the first and third drivers. The effect of decreasing the rotating weight at the crank pin by 63 lb. would be to increase the downward pressure at the main driver when the counterweight is down and to decrease it when the counterweight is up—to decrease the dynamic augment effect if the main driver is underbalanced and to increase it if overbalanced. The effect upon the two adjacent drivers would be to decrease the equivalent single load pressure somewhat for counterweight down, but the effect would be small. The data of Series 7 and 8 for stresses at the main driver are indefinite on the matter of effect of counterbalance; the points are quite scattered and it was found to be impracticable to draw a curve for a speed of 60 miles per hour, and that for 45 miles per hour was less regular than those found in other tests. The diagrams give the impression that the counterbalance effect at this wheel was small and rather variable for the different positions of the counterweight. For a speed of 60 miles per hour the calculated change in stress in rail at the main driver due to the 63-lb. change in counterbalance would be a decrease of 1 500 lb. per sq. in. when the counterweight is up and an increase of the same amount when it is down, and for a speed of 45 miles per hour a change of 900 lb. per sq. in., and it seems probable that such a change was effected.

15.—Test with the Mikado Type Locomotive.—The tests with the Mikado locomotive No. 1769 of the Illinois Central Railroad were made principally to find the effect of speed and counterbalance upon stress in rail for this type of freight locomotive. The results are concordant and generally definite and in these respects are more satisfactory than most of the tests which have been made. Sample plots of observed values of stress in rail are given in Figs. 18 to 22, which give also the curve of average stress throughout the revolution of the driver, the belt of most frequent values, and a line representing the mean of the stresses found in one revolution. Fig. 23 gives curves of average stress throughout a revolution for the several wheels at the four speeds. Fig. 24 shows the stress at high point and low point of counterweight taken from these curves. These values of stress in rail are given in Table 11, together with the mean value for the curve of average stress.

Table 12 gives the total ratio (combined speed and counterbalance effect), speed effect ratio, $\frac{S_m}{S_5}$, and counterbalance effect ratio, the

TABLE 11.—STRESSES IN RAIL WITH MIKADO TYPE LOCOMOTIVE OF THE ILLINOIS CENTRAL RAILROAD. MAXIMUM, MINIMUM, AND MEAN VALUES FROM CURVES.

Stresses are given in pounds per square inch at base of rail

Speed, in miles per hour.	Position of counterweight.	Trailer.	Driver Number.				Front truck wheel.
			4	Main.	2	1	
5	Mean value	15 800	16 500	14 200	14 200	15 600	8 800
25	Up	21 400	16 600	20 800	15 600	15 600	
	Down	15 600	24 000	12 000	20 300	22 400	
	Mean value	18 500	20 600	16 100	18 000	19 700	12 700
35	Up	22 400	15 600	25 000	13 000	13 000	14 600
	Down	18 200	25 000	10 400	23 400	25 000	12 000
	Mean value	19 000	20 100	17 700	18 200	19 000	13 100
45	Up	26 500	15 600	30 500	16 600	15 600	19 600
	Down	21 300	32 800	11 500	26 500	29 100	11 500
	Mean value	24 200	24 000	20 800	21 200	22 000	15 400
Calculated stress under static load		16 300	18 200	15 300	12 500	16 500	9 600
Calculated additional stress due to counterbalance at 45 miles per hour		200	4 300	3 200	3 200	4 300	400

nomenclature being the same as was used in the discussion of the tests with the Santa Fe and Pacific locomotives and the stress at 5 miles per hour being the divisor used in obtaining the ratios.

It will be noted that the stress at the first, second, and fourth drivers is greatest when the counterweight is down, and that the stress at the main driver is greatest when the counterweight is up. The stress at the trailer is greatest when the counterweights of the drivers are somewhat past their high position. The truck wheel shows the effect of counterbalance, the high stress in rail occurring when the counterweights of the drivers are slightly past the high position (about one-seventh of a revolution), and the corresponding low stress at the opposite position. The results indicate that the main driver is underbalanced for rotating parts, and that the other drivers are overbalanced.

The figures for counterbalance weights given by the Motive Power Department of the Illinois Central Railroad (see Table 3, page 17), indicate the same condition of counterbalance for each driver, 263 lb. overbalance for rotating parts (to balance 60% of the reciprocating parts, considered to be taken by the four drivers equally). Not only is the position of counterweight of the main driver which gives the highest stress in rail the opposite of that obtained by analysis for the weights given in the table, but the counterbalance effect found for the several drivers is much larger than the calculated values. For the first, second,

TABLE 12.—RATIOS OF MAXIMUM STRESS, MEAN STRESS, AND ADDITIONAL STRESS TO STRESS AT 5 MILES PER HOUR, MIKADO TYPE LOCOMOTIVE OF THE ILLINOIS CENTRAL RAILROAD.

Position of counterweight.	TRAILER.		DRIVER NUMBER.								TRUCK WHEEL.	
			4		Main.		2		1			
	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.
Average stress at 5 miles per hour assumed as basis of comparison	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
25 MILES PER HOUR.												
Total effect $\frac{S_{25}}{S_5}$	1.36	0.99	1.01	1.46	1.46	0.84	1.10	1.42	0.97	1.43	. 9	1.49
Effect of speed $\frac{S_m}{S_5}$	1.17	1.17	1.25	1.25	1.13	1.13	1.26	1.26	1.26	1.26	.49	1.49
Effect of counterbalance (increase or decrease) $\frac{S_{25} - S_m}{S_5}$	+ 0.18	− 0.18	− 0.24	+ 0.20	+ 0.33	− 0.29	− 0.17	+ 0.16	− 0.29	+ 0.17	0.00	0.00
Calculated effect of counterbalance	0.00	0.00	− 0.07	+ 0.07	− 0.06	+ 0.06	− 0.08	+ 0.08	− 0.08	+ 0.08	+ 0.02	− 0.02
35 MILES PER HOUR.												
Total effect $\frac{S_{35}}{S_5}$	1.41	1.15	0.95	1.49	1.75	0.73	0.91	1.64	0.83	1.60	1.71	1.40
Effect of speed $\frac{S_m}{S_5}$	1.20	1.20	1.21	1.21	1.25	1.25	1.28	1.28	1.22	1.22	1.54	1.54
Effect of counterbalance (increase or decrease) $\frac{S_{35} - S_m}{S_5}$	+ 0.21	− 0.05	− 0.26	+ 0.28	+ 0.50	− 0.52	− 0.36	+ 0.36	− 0.39	+ 0.38	+ 0.17	− 0.13
Calculated effect of counterbalance	+ 0.01	− 0.01	− 0.14	+ 0.14	− 0.13	+ 0.13	− 0.16	+ 0.16	− 0.16	+ 0.16	+ 0.03	− 0.03
45 MILES PER HOUR.												
Total effect $\frac{S_{45}}{S_5}$	1.68	1.35	0.95	1.99	2.14	0.91	1.15	1.86	1.00	1.87	2.29	1.34
Effect of speed $\frac{S_m}{S_5}$	1.53	1.53	1.46	1.46	1.47	1.47	1.49	1.49	1.41	1.41	1.81	1.81
Effect of counterbalance (increase or decrease) $\frac{S_{45} - S_m}{S_5}$	+ 0.15	− 1.18	− 0.51	+ 0.53	+ 0.67	− 0.55	− 0.34	+ 0.37	− 0.41	+ 0.45	+ 0.48	− 0.47
Calculated effect of counterbalance	+ 0.01	− 0.01	− 0.24	+ 0.24	− 0.21	+ 0.21	− 0.26	+ 0.26	− 0.26	+ 0.26	+ 0.05	− 0.05

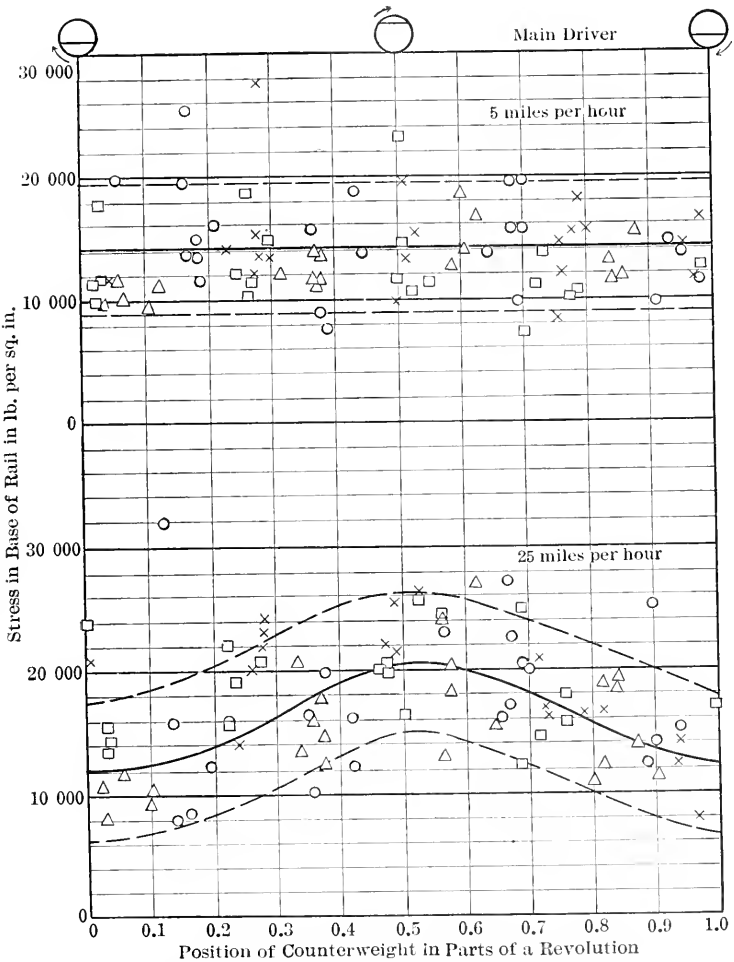


FIG. 18.—OBSERVED VALUES OF STRESS IN RAIL WITH MIKADO TYPE LOCOMOTIVE OF THE ILLINOIS CENTRAL RAILROAD.

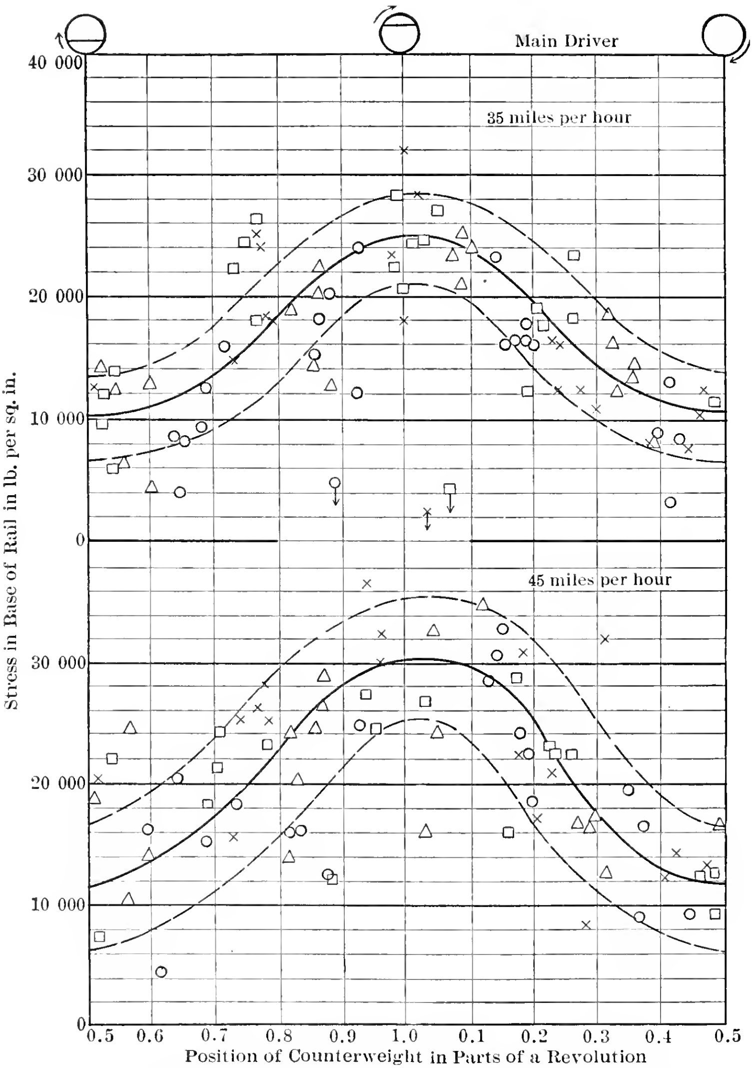


FIG. 19.—OBSERVED VALUES OF STRESS IN RAIL WITH MIKADO TYPE LOCOMOTIVE OF THE ILLINOIS CENTRAL RAILROAD.

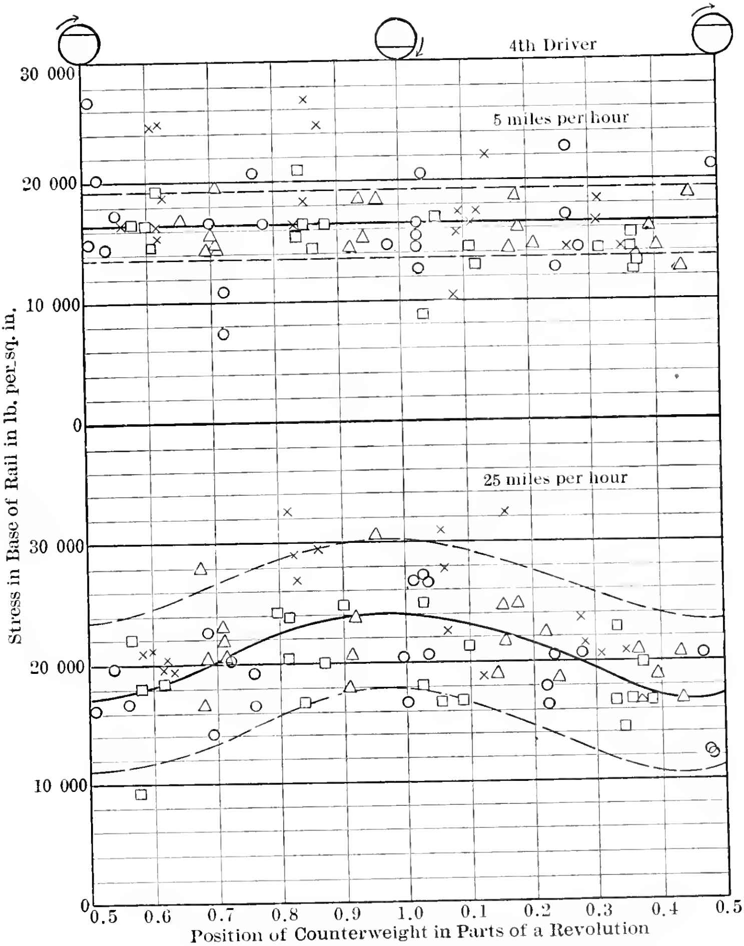


FIG. 20.—OBSERVED VALUES OF STRESS IN RAIL WITH MIKADO TYPE LOCOMOTIVE OF THE ILLINOIS CENTRAL RAILROAD.

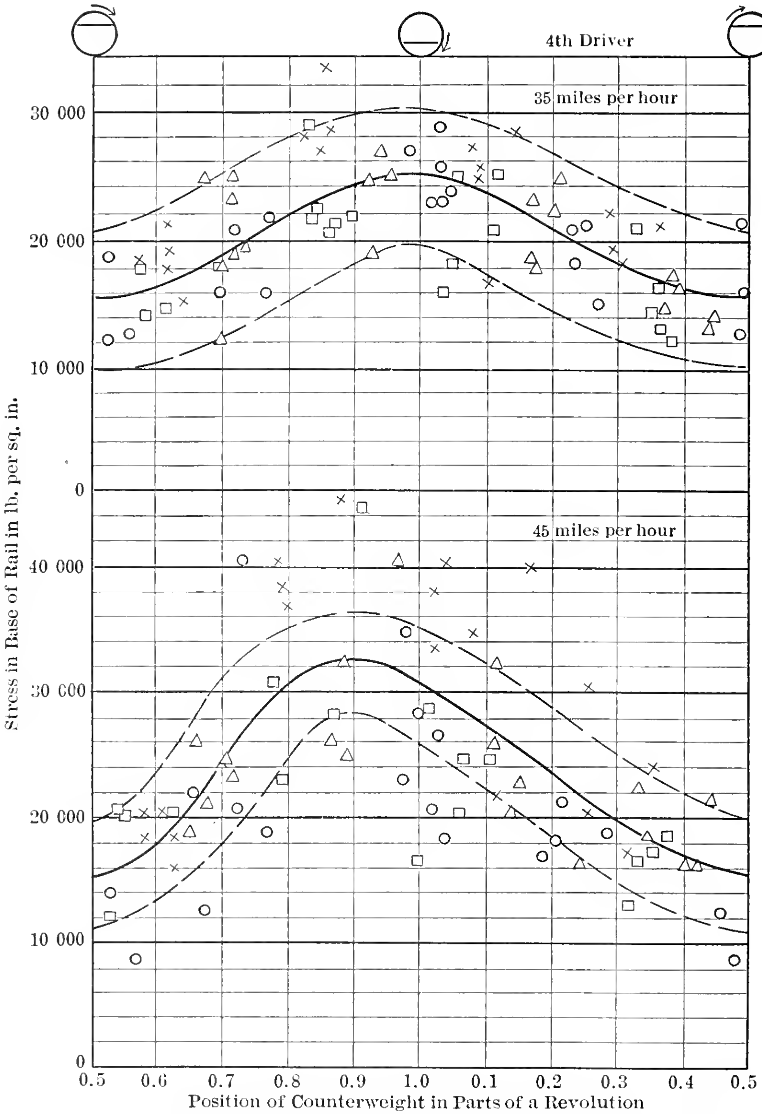


FIG. 21.—OBSERVED VALUES OF STRESS IN RAIL WITH MIKADO TYPE LOCOMOTIVE OF THE ILLINOIS CENTRAL RAILROAD.

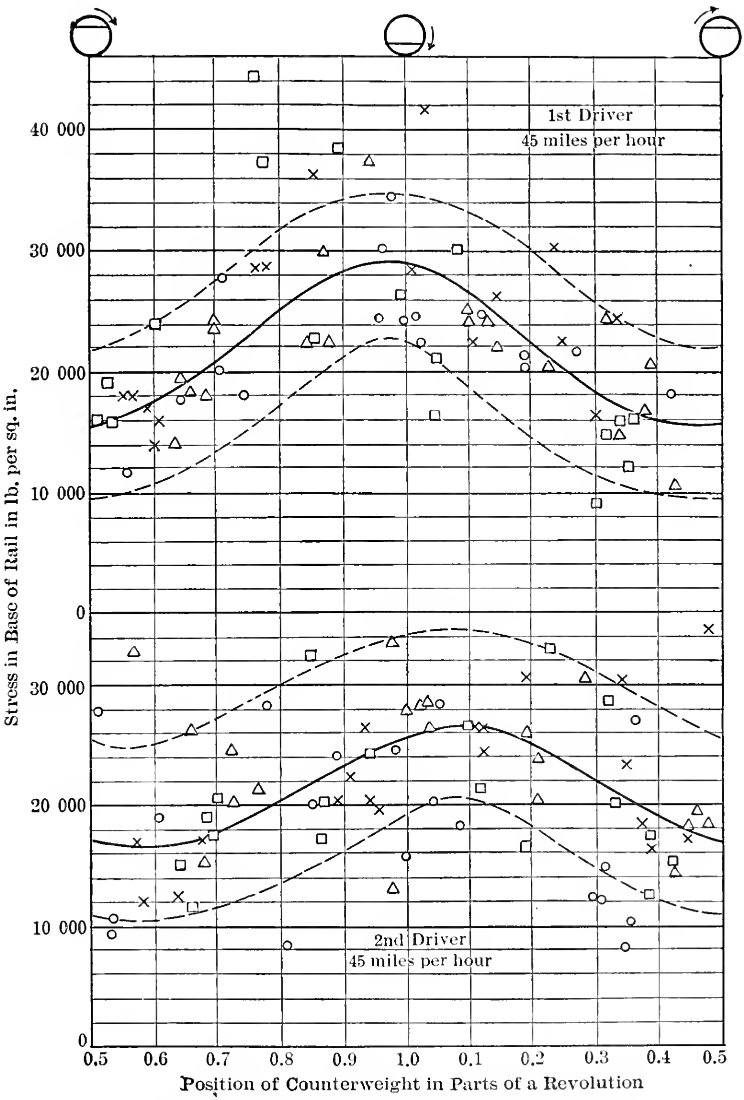


FIG. 22.—OBSERVED VALUES OF STRESS IN RAIL WITH MIKADO TYPE LOCOMOTIVE OF THE ILLINOIS CENTRAL RAILROAD.

and fourth drivers and for the speeds of 25, 35, and 45 miles per hour the average of the ratios expressing effect of counterbalance given in Table 12 is more than twice the calculated value. For the main driver at these three speeds the ratios expressing the counterbalance effect (0.33 at 25 miles per hour, 0.50 at 35 miles per hour, and 0.67 at 45 miles per hour) are three to four times the calculated values, and the high stresses occur when the counterweight is up instead of when it is down as would be expected from the counterbalance data given. A consideration of the planes in which the several rotating parts act only partly explains the discrepancy in the case of the main driver.

No explanation is offered for the remaining discrepancies. Possibly the weights of parts may not be correctly reported, and their distribu-

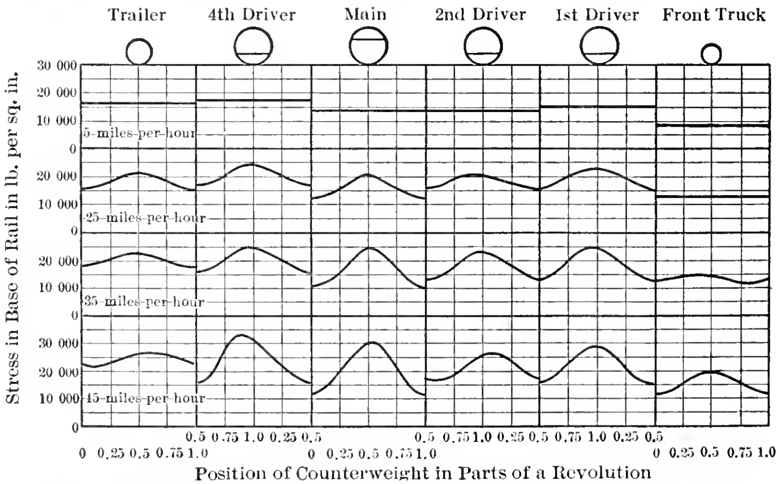


FIG. 23.—CURVES OF AVERAGE STRESS IN RAIL THROUGHOUT REVOLUTION OF DRIVER, MIKADO TYPE LOCOMOTIVE OF THE ILLINOIS CENTRAL RAILROAD.

tion may also not be correct. Although the counterbalance effects are generally not large, the additional stress at main driver at 35 miles per hour (the speed limit given by the railway regulations) is 50% as great as the stress at 5 miles per hour, and the stresses due to counterbalancing would be materially less if the counterbalance effects were in the same direction for each driver.

The effect of speed alone, as shown by the speed ratios in Table 12, is about the same for the several drivers. The ratios for truck wheel and for trailer are considerably higher at the higher speeds.

16.—Relation of the Stresses at the Two Sides of the Base of Rail.— In the first progress report it was shown that lateral bending of the rail occurred to a considerable extent; that most frequently the rail was bent outwardly at a point under a wheel and inwardly at a point between

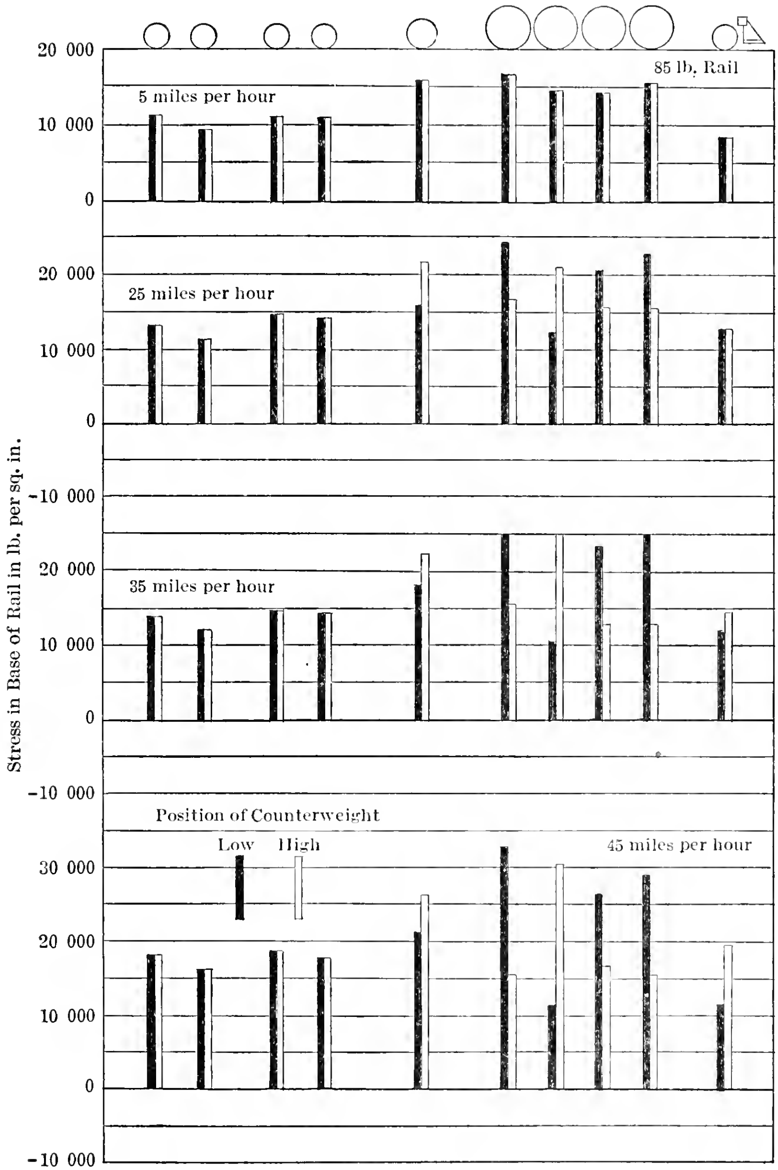


FIG. 24.—STRESS IN RAIL AT HIGH AND LOW POSITION OF COUNTERWEIGHT, MIKADO TYPE LOCOMOTIVE OF THE ILLINOIS CENTRAL RAILROAD.

wheels, though a flexure opposite to this also was frequent; that the change in gauge of track accompanying this bending was measurable; that the bending occurs with the locomotive at rest and at low speeds as well as at higher speeds; and that the stress at the outer edge of the base of rail may occasionally reach three or more times that at the inner edge. An examination of the data of some of the tests described in this report has been made with a view of supplementing the information given in the first report.

A study has been made of Series 1 and 2 (with the Santa Fe type locomotive), Series 10 and 12 (with the Pacific type), and the Series made on the Illinois Central Railroad (with the Mikado type). The stresses for the two sides of the base of rail were plotted separately according to the position of the counterweight, and curves were drawn to represent the trend and position of the points throughout the revolution for stress at both outer edge of base of rail and inner edge. The curves for stress at outer edge and at inner edge are quite similar, that for outer edge being higher than the curve of average stress in base of rail heretofore reported, and that for inner edge lower. The point of maximum stress for outer edge generally comes a little later in the revolution than that for inner edge.

It was found that the average of all the observations for the outer edge was greater than that for the inner edge. This conclusion applies at all speeds and at all positions of the counterweight for all the drivers and to the higher stresses found as well as to the lower. It also applies to the trailer and to the tender wheels. The average of the stresses at the outer edge for the several wheels ranges from, say, 20 to 50% greater than the average at the inner edge; that is, the average stress at the outer edge is from 9 to 20% greater than the mean stress in base of rail, which is the stress heretofore used.

This indicates that a general condition exists tending to give outward lateral bending in rail. No further investigation has been made to determine what that condition is. It may be noted that the difference in stress at the two sides of the rail was as great, or greater, under the main driver as under the other drivers. In the case of the Santa Fe type this driver has no flange and was slightly worn. While the number of observations giving the higher stress at the outer edge was considerably greater than that at the inner edge, the number having the opposite relation was by no means small, showing that the swaying of the locomotive laterally is a factor in the problem.

A similar relation exists at points between wheels in the region of negative bending moment, though here the lateral bending is generally in the opposite direction from that at the wheel and the average stress at the inner edge is greater than that at the outer edge.

More important than the average value at the edges of the base of rail are the relative values of the individual observations. The ratios of

the stress at edge to the mean stress in base of rail were plotted. A study of these shows that in 15 to 20% of the observations, the stress at the outer edge is 33% or more greater than the mean stress in base of rail, in a few cases reaching an excess of 50% or more, and that this holds good throughout the revolution of the driver. An excess of 20% is quite common. A stress at inner edge 33% greater than the mean stress was found in, say, 5 to 8% of the observations. As an example of a large difference in stresses at the two edges, though not of a high ratio of stresses, values for the main driver of the Santa Fe type at a speed of 50 miles per hour may be cited, 36 400 lb. per sq. in. at the inner edge, and 55 000 lb. per sq. in. at the outer.

The lateral bending in rail has some bearing on the design of rail section and on the design of tie plates. It will be seen that for the rail sections used, a ratio of stress at outer edge to mean stress in base of rail having a value of 1.33 means that the lateral bending moment in the rail is about 8% of the vertical bending moment required to develop the mean stress. It should be noted that the results herein presented were obtained with track which may be said to be in ordinarily good condition; the results given in the first progress report for track in poorer condition and for track with decayed ties show that the amount of lateral bending may be materially greater and that therefore the condition of the track is an important element in the problem.

17.—General Discussion.—In Figs. 25, 26, 27, and 28 the ratios for total effect, speed effect and counterbalance effect given in Tables 6, 8, 10, and 12 have been plotted. These ratios show the relation between the stress in rail at the several higher speeds and the stress in rail existing at a speed of 5 miles per hour. In all the series the total effect ratios are concordant and show a marked increase of stress with speed, the increase being faster than the first power of the speeds. The method used in making a division of this total effect ratio into effect of speed alone and effect of counterbalance is of course not accurate, and it may be expected that a large counterbalance effect will result in an increased speed effect as well. Fig. 29 gives the ratios for the average speed effect for the tender wheels of the three types of locomotives used, as well as the values of the average stresses at these wheels.

It will be noted that the increase in stress in rail at drivers and trailer beyond 5 miles per hour due to speed alone, varies almost directly as the increase in speed, though in a few instances it is at a somewhat faster rate. Averaging the values of the ratios at the drivers and trailer and for comparison using a speed of 50 miles per hour in all cases, it is seen that for this speed the increase in stress in rail due to speed alone over that at 5 miles per hour will be about 70% for Series 1 and 50% for Series 2 (average of 60% for the Santa Fe type locomotive used), about 35% for the Pacific type locomotives, and about 50% for the

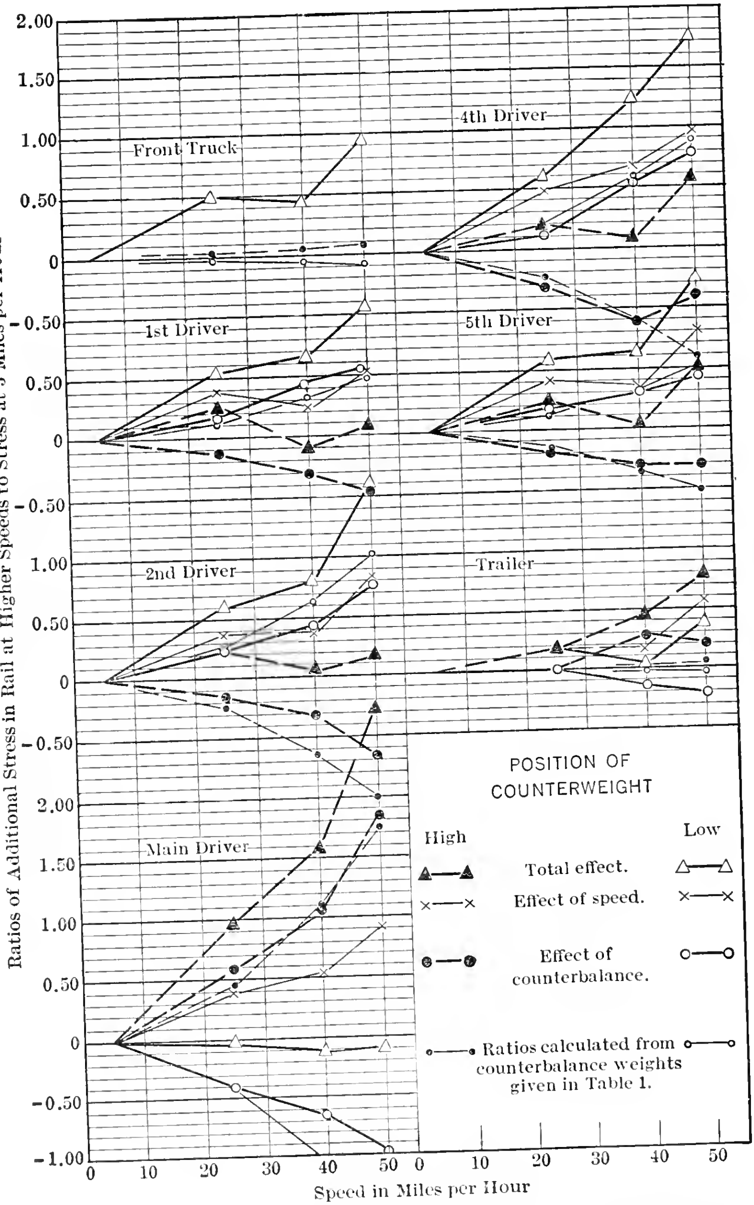


FIG. 25.—RATIOS OF TOTAL EFFECT, SPEED EFFECT, AND COUNTERBALANCE EFFECT TO STRESS AT 5 MILES PER HOUR, SERIES 1, SANTA FÉ TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

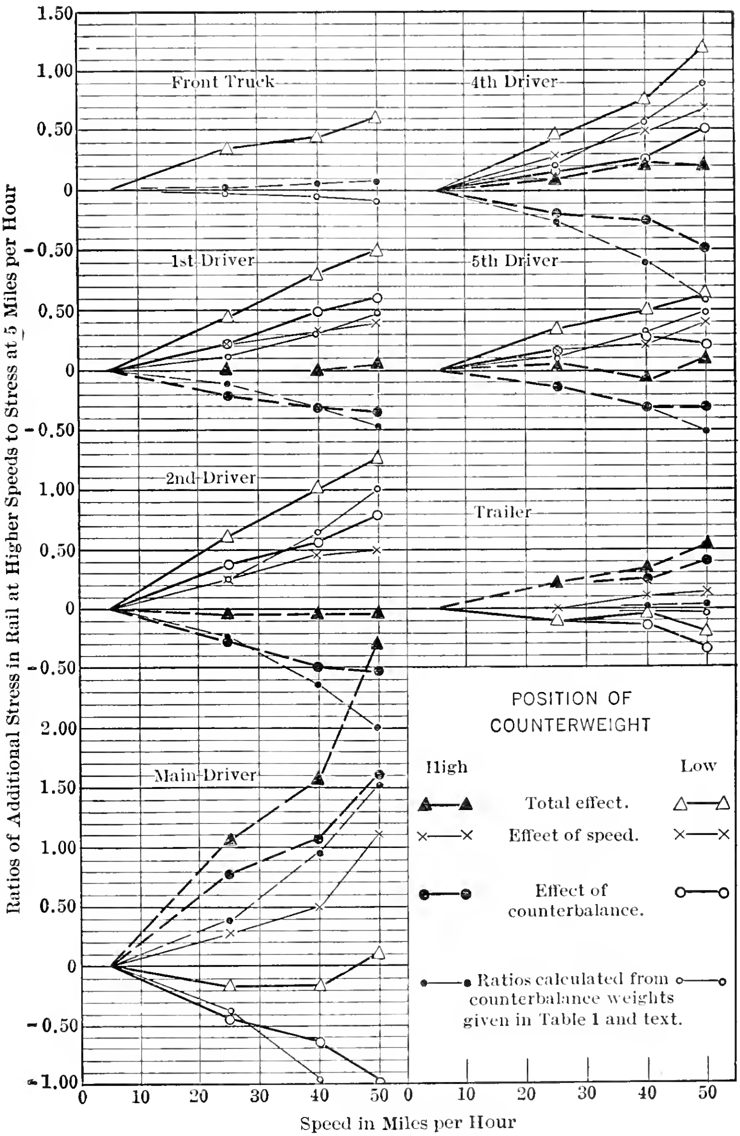


FIG. 26.—RATIOS OF TOTAL EFFECT, SPEED EFFECT, AND COUNTERBALANCE TO STRESS AT 5 MILES PER HOUR, SERIES 2, SANTA FÉ TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

Mikado type locomotive. At the tender wheels, the stresses in rail increase almost directly as the increase in speed. The increase in the stresses at 50 miles per hour over those at 5 miles per hour at the tender wheels is approximately as follows: Series 1, 50%, Series 2, 100% (an average of 75% for the Santa Fe type locomotive); Pacific locomotive 100%; and Mikado locomotive, 75 per cent. It is seen that the ratios found for the drivers are in general less than those for the tender

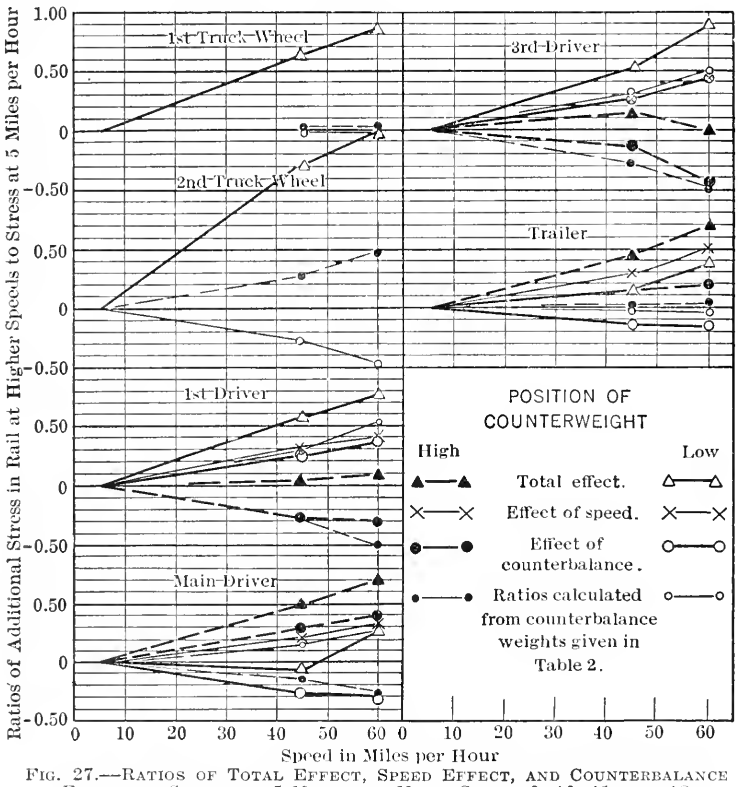


FIG. 27.—RATIOS OF TOTAL EFFECT, SPEED EFFECT, AND COUNTERBALANCE EFFECT TO STRESS AT 5 MILES PER HOUR, SERIES 9, 10, 11, AND 12 COMBINED, PACIFIC TYPE LOCOMOTIVE OF THE ST. LOUIS-SAN FRANCISCO RAILWAY.

wheels (the ratios do not include the effect of counterbalance), and the increase at the tender wheels varies considerably for the different locomotives. In some of the locomotives (particularly the Santa Fe type) the increased stress at some of the wheels is materially higher than the average values quoted above.

The counterbalance effect at low and high position of counterweight, with both underbalance and overbalance, is brought out in Figs. 25, 26, 27, and 28. It appears that with the main driver underbalanced

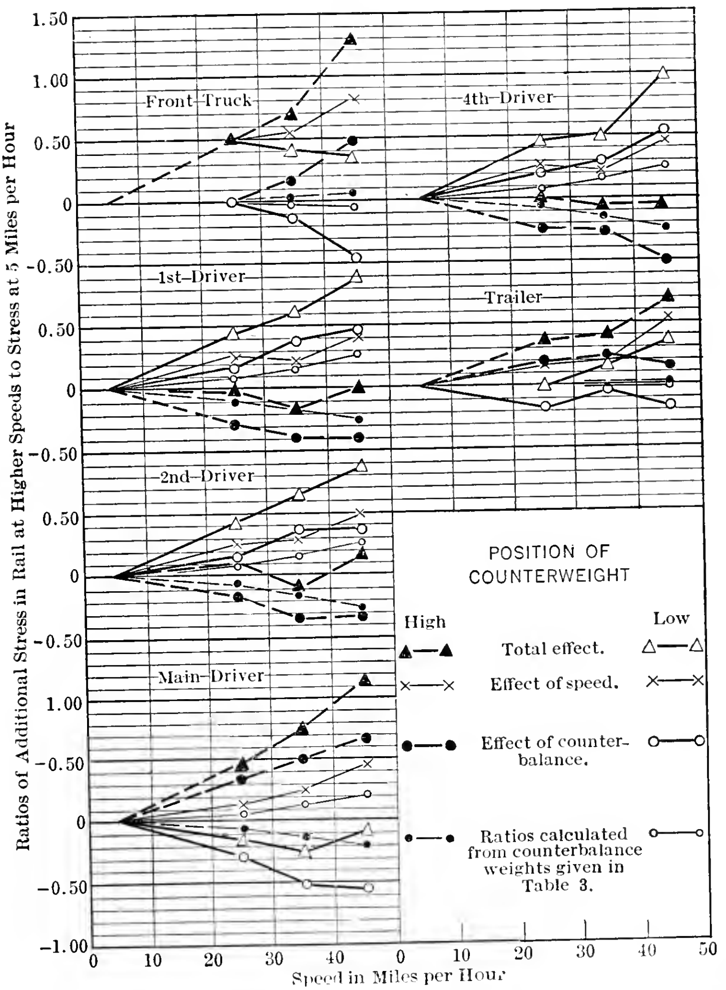


FIG. 28.—RATIOS OF TOTAL EFFECT, SPEED EFFECT, AND COUNTERBALANCE EFFECT TO STRESS AT 5 MILES PER HOUR, MIKADO TYPE LOCOMOTIVE OF THE ILLINOIS CENTRAL RAILROAD.

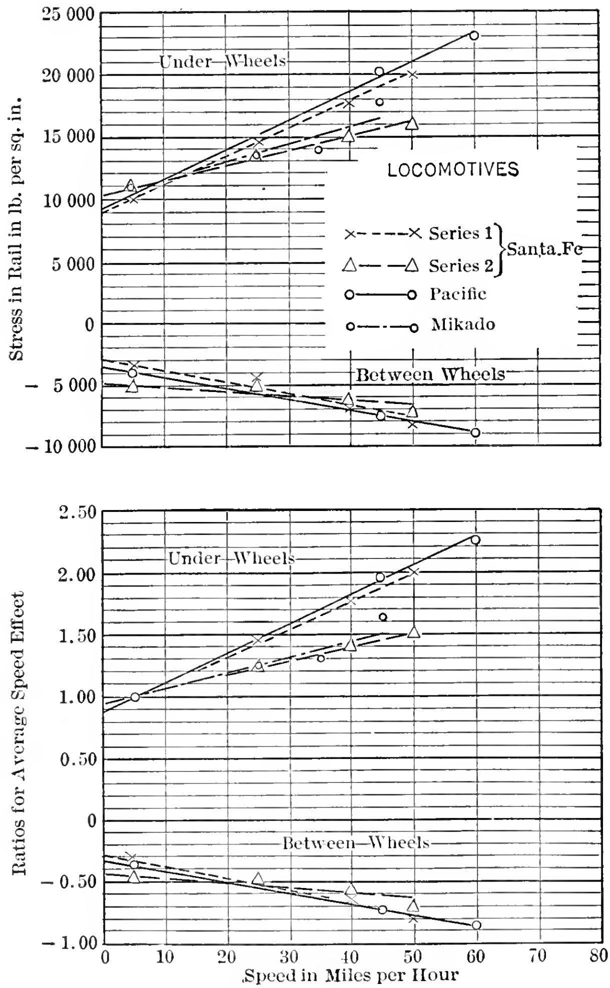


FIG. 29.—AVERAGE STRESSES AND RATIOS FOR AVERAGE SPEED EFFECT FOR THE TENDER WHEELS OF THE THREE TYPES OF LOCOMOTIVES.

and the other drivers overbalanced there is some transfer of pressure through the equalizer bars, tending to reduce somewhat the stresses due to counterbalance, but the effect is not very definite and seems to be uncertain. The stress due to counterbalance increases much faster than the increase in speed, though not always as fast as the square of the speed. The average increase in stress at the several drivers due to counterbalance effect, as indicated by the ratios in the figures, for a common speed of 50 miles per hour over the stress at 5 miles per hour is about 90% for Series 1 and 80% for Series 2 (average 85% for the Santa Fe type locomotives used); 30% for the Pacific type; and 60% for the Mikado type. The increase in stress at the main driver in each case is greater than this average, and with the Santa Fe type very much greater.

Points representing the calculated counterbalance effect ratio are also given in Figs. 25, 26, 27, and 28; they are based upon the counterbalance weights given in Tables 1, 2, and 3 without consideration of the effect of the planes of rotation of the rotating parts being in different planes or of other distributing elements. It will be noted that in a number of cases there is a considerable discrepancy between the observed and the calculated ratios.

The following general observations are made:

It is evident that there is a decided advantage to the track in making the counterbalance of the several drivers differ but little from each other and from that condition which will give the best results, even though opposing conditions of counterbalance in the main driver and the adjoining drivers may have some neutralizing effect. An underbalance on one driver and an overbalance on an adjoining one will give a very undesirable cumulative effect.

It is of course to be expected that when the locomotive is working the downward pressure of the main driver will be increased over that obtaining when the steam is shut off as was the case in the tests here discussed.

For the Santa Fe type locomotives tested the stresses at the main driver were much greater than at the other drivers.

Considering the stresses developed in the tests it is not strange that great injury to track is done by poorly balanced locomotives run at high speed. Even at lower speeds, where kinking of rail does not result, the punishment of the track is much greater than will be caused by well-balanced locomotives. The effect of counterbalance and speed is to add greatly to the load to be carried by rail, tie, and ballast.

Effort may well be made to reduce the counterbalance effect on stress in track by use of the best methods of design of locomotive and by the use of material which will permit a minimum of counterbalance effect in both rotating and reciprocating parts.

It is important that care be taken to determine the actual weights and position of counterweights and the actual properties of the side rods and connecting rods. Care should be taken to learn whether the assumed division of load among the drivers in the completed locomotives is obtained.

Locomotives will give very different stresses in rail at the different wheels according to the wheel spacing, the division of load, and the effect of adjoining wheels.

It is apparent from analysis that for the spacing of wheels in the three types of locomotives the stress at the trailer under static load or at low speeds will be relatively large if the weight on the trailer is greater than, say, 75% of the average weight on drivers; and the tests would indicate that for locomotives with even fairly good counterbalancing a discrepancy at low speeds between the stress at the trailer and the stress at a driver, due to a relatively heavy load on the trailer, may be expected to exist also at higher speeds.

It was found that the wheels of the tenders of the different types of locomotives gave quite different effects of speed on the stress in rail.

Attention may well be called to the method herein used in calculating the stress in rail for a combination of driver loads. The method ordinarily adopted in taking into account the counterbalance effect uses the dynamic augment for the given driver only. In getting the stress-producing bending moment in the rail, however, it is necessary to take into account the dynamic augment also of the adjoining drivers. With the main driver underbalanced and the adjoining drivers overbalanced the pressures given by the adjacent drivers are especially influential and the effect of the combined loads should not be overlooked. It should be added, too, that the effect of counterbalancing upon bending moment in rail is different from the effect upon rail depression and pressure on rail—these must be calculated separately.

In the discussion of counterbalance, and the calculation of the stress produced in the rail, no attempt has been made to go into the complications of the problem involved in the yielding of the locomotive springs and of the track acting as a spring, the effect of the rotating parts not being in the same plane, and other disturbing elements.

The tests were made on 85-lb. rail. It is felt that the effect of speed and counterbalance in producing stress in rails of other weight will follow in general the results found with the 85-lb. section. The increase in stress at a given speed over the stress at 5 miles per hour may be considered to be produced by additional loads at the drivers, due to speed and counterbalance, and the amount of these additional loads may be calculated by the use of the analytical methods outlined in the report. The loads thus found for speed and counterbalance effect

may be used in judging of the effect of speed and counterbalance with rails of other sections. The calculations for stress in a section may be made on the basis of the analysis for bending moments given in the first progress report, the section modulus of the given rail being used in calculating the stress developed by the bending moment found.

It is evident that wheel spacing, distribution of load among drivers and trailer, and counterbalancing have a marked influence upon the stresses developed in rail and also in the track structure below the rail. Adequate consideration therefore should be given to these elements in designing locomotives if the track is not to be called upon unduly to carry loads and to resist stresses which are unnecessary or excessive. The uncertainty which may exist concerning exact conditions of counterbalance is a matter which warrants greater attention.

III. Track Depressions.

18.—Depression of Track under Load and Modulus of Elasticity of Rail Support.—In the first progress report of the Committee the general question of the depression of track under load was considered and the effect of the make-up and condition of the track structure upon stresses in rail and distribution of load among the ties was discussed. In connection with the tests to determine the flexural action of ties in track (presented under "IV.—Depression, Flexure, and Bearing Pressure of Cross-Ties"), made since that report was prepared, tests have been made to obtain the depression of the track under the conditions which obtained when these tests of ties were made. A purpose of making these profiles of rail depression was to determine the proportion of the load applied to the rails which may be considered to be taken by a single tie. The tests served also to show the relative effects of different amounts of load and something of the general condition of the track.

Under the best conditions, with freshly tamped track, the depression at any tie may be expected to be nearly proportional to the load applied to the rail and likewise proportional to the load taken by the individual tie. For track not recently tamped or in poor condition there will be a slight play between the tie and the ballast along parts of its length, and part of the resistance before the tie takes bearing along its length will be due to the bending of the tie under the action of the lighter loads. These and other influences found in track not in the best condition make the line representing the relation of track depression to applied load vary from a straight line through at least a part of its length.

In Fig. 30, the relation between tie depression and load on tie for track in best condition is illustrated at (*a*). The vertical distances represent the depression of rail; the horizontal distances are proportional to the load on the track. This condition gives a constant modulus

of elasticity of rail-support—the term defined in the first progress report as the pressure per unit of length of each rail required to depress the track one unit and which was found to be of considerable service in analytical investigations.

At (*b*) is illustrated the case where a light load produces considerable depression and greater loads result in additional amounts of depression which are proportional to the increments of load. The distance from the origin to the point where the line passing through the points intersects the vertical axis may be considered to represent in part the play or space between the bottom of the tie and its bed when

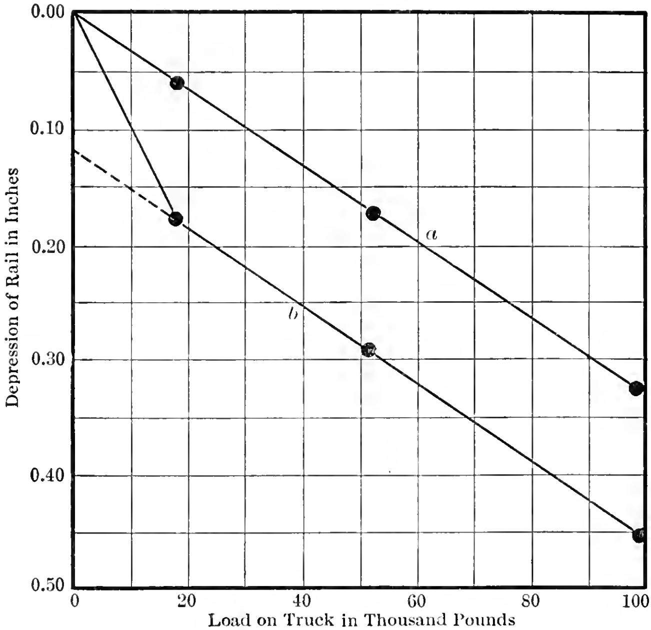


FIG. 30.—TYPICAL LOAD-DEPRESSION DIAGRAM.

the tie is not under load, though of course there is some bearing resistance by the tie for track depressions less than the amount of this intercept, and a part of the total play may be between the rail and the tie. In general the direction of the line through the points obtained by the several loads represents the load-depression relation and is closely parallel to the line found for well-tamped track. For general purposes the direction of this part of the line may be used in determining the value of the modulus of elasticity of rail-support.

19.—Track-Depression Tests on Illinois Central Railroad.—In the tests of track depression made in 1918 the load was furnished by cars loaded in such a way as to give the desired weight on the truck at one

end of the car. The end of the car to be used in the test was weighed on track scales. In the use of the data of the tests it is assumed that each wheel of the car truck carried one-fourth of the weight so found. In the tests on the Illinois Central Railroad three loads were used, 100 000, 53 000, and 18 000 lb. on a single truck; that is, 25 000, 13 250 and 4 500 lb. on each of the four wheels of the truck. The smallest load was taken as being sufficiently heavy to bring the tie to a full bearing on its bed and to eliminate any play which may exist between rail and tie and tie and ballast. The wheel base of the truck was 5 ft. 6 in. The distance between trucks (31 ft. center to center for the car giving loads of 100 000 and 53 000 lb. and 29 ft. for the one giving 18 000 lb.) was such that the load on the trucks at the farther end of the car did not have a large effect upon the track depression at the middle of the length of the car. The center of the truck was placed at the middle of the length of the rail, except on Section *K* and on cinder ballast (alternate joints) where the load was placed at the quarter points of the rail.

The level bar described in the first progress report was used in taking the levels along the rails for zero load and for the other loads from which the track depressions were computed. The method of making a test was the same as that described in the first progress report. A fixed reference stake was placed 80 in. from the rail and levels were carried from this bench mark to the rail by means of the level bar for each set of levels. A set of levels along the portion of the rail measured was first taken for zero load. One of the loads was then applied and levels were run over the stretch of rail, and this was followed with measurements at the remaining loads. In all cases levels were run on both rails.

The tests were made on the main line of the Illinois Central Railroad about two miles north of Champaign, Ill., on the track previously prepared for the track tests and on the sections of track marked *B, C,* and *K* in Fig. 26 of the previous report. The ties were the 6 by 8-in. by 8-ft. sawed oak ties furnished for the test track in 1914. The rail on Sections *B* and *C* was the 85-lb. rail of Am. Soc. C. E. section, the same as was in the track in the previous tests, and that on Section *K* was the 125-lb. rail also used in the other tests. Besides these tests, a test was made on the north-bound freight lead shown in Fig. 26 of the previous report, which has 85-lb. rail and 12 in. or more of cinder ballast, and the usual run of hewn oak ties with a few sawed ties.

The main track had not been tamped for some time, a year or more, and although only passenger trains used it ordinarily, the track was not in good surface condition. The track depressions found and the flexural action of the ties go to show looseness and play between tie and ballast. Attention should be called, too, to the scantiness of the shoulder

of ballast on the outer side of the south-bound track (see Fig. 43), particularly on Section *B*, which gave little support to the ties at this end. Altogether, however, the track was not in bad riding condition and may be said to be representative of much well-made track at times when it has received the effect of traffic over a considerable period after tamping. At one location, *B*-2, the track was tamped slightly between tests but not enough to improve its condition materially.

On Section *B*, tests were made at two locations (adjoining rails) which will be designated *B*-1 and *B*-2. This section has 12 in. of stone ballast. On Section *C*, the two locations (also on adjoining rails) will be designated *C*-1 and *C*-2. This section has 6 in. of stone ballast. At Section *K* the ballast is 24 in. deep.

Figs. 31, 32, 33, 34, and 35 give the track-depression profiles. The loads given are the total loads on a single truck. The levels were taken for a length of 40 ft. or more, depending upon the location of the joints, and the results for the full length are given for Location *K*, *C*-1, *C*-2 and cinder ballast; for the other locations the profiles for a shorter length are shown, including all the ties which carry loads of any amount. In Figs. 32 and 33 load-depression diagrams have been plotted below the profiles for different points along the rail, the horizontal distances being proportional to the load on the truck; the intercept on the vertical axis of the straight line used is taken as the vertical play in the track. In several cases the measurements for the east rail were found to be inconsistent and unreliable, and these have been discarded.

In making the calculations for tie reactions, the amount of the play found from the load-depression diagrams was subtracted from the observed tie depression; the total load was divided by the sum of the net depressions for all the ties carrying load; the product of this quotient and the net depression of a tie was taken as the load or reaction of that tie. If the play found for different parts of the track-depression profile was fairly uniform the average play was used. In some cases the play differed considerably at points along the profile and it was necessary to use that found for each tie. Generally speaking, the length of rail considered included all the ties showing a positive net depression. As there was some negative reaction on ties beyond these limits the actual load on the ties considered was in reality greater than the applied load.

In Table 13 the tie reactions are given for the several tests. The values are given in terms of the load on truck at the end of the car used. The ratios given in the table are more convenient for making comparisons than weights. Values found from the higher loads are given; for the low load the effect of the tie play is so great that comparison based on this load would not be especially useful. If gross depressions had

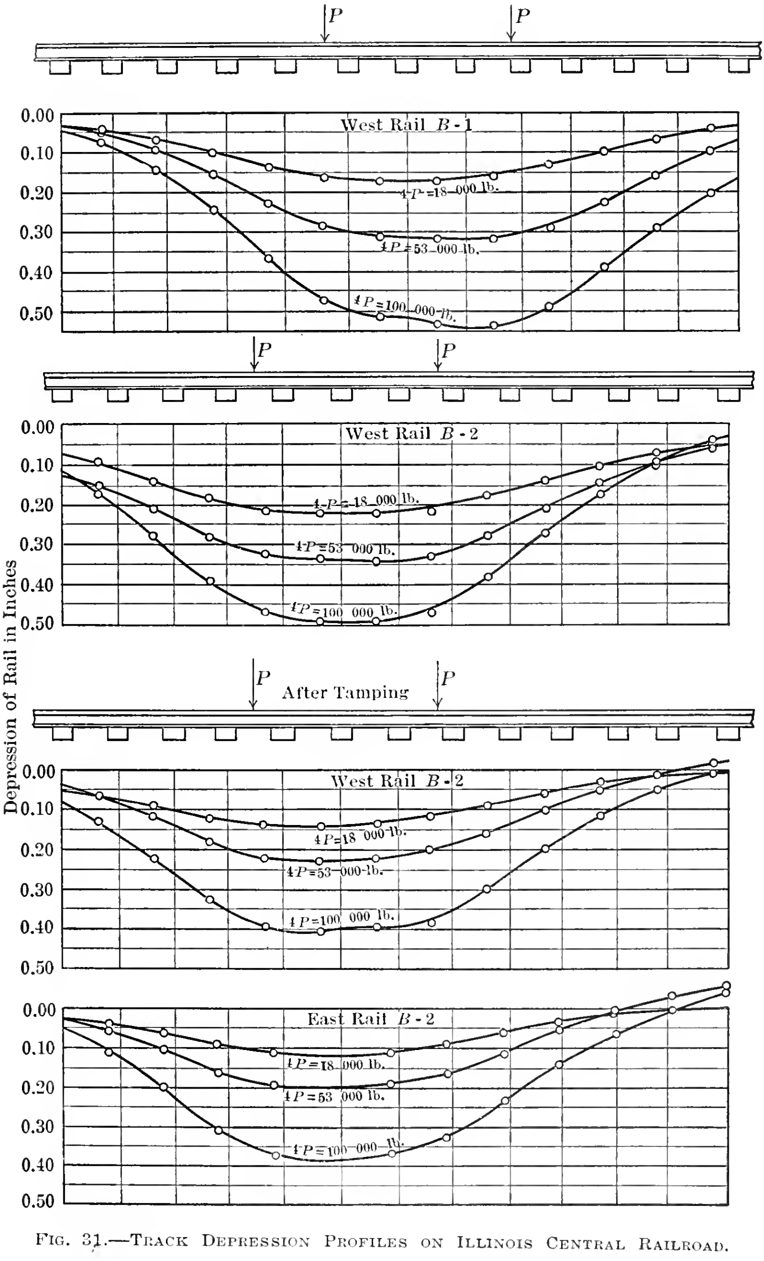


FIG. 31.—TRACK DEPRESSION PROFILES ON ILLINOIS CENTRAL RAILROAD.

been used instead of net depressions the tie reactions throughout the middle of the track-depression profile would be smaller than the values given in Table 13 and those away from the loads would be greater.

The values in Table 13 indicate that for this two-axle loading and 85-lb. rail the tie reaction at the wheel is from 13 to 16% of the load on

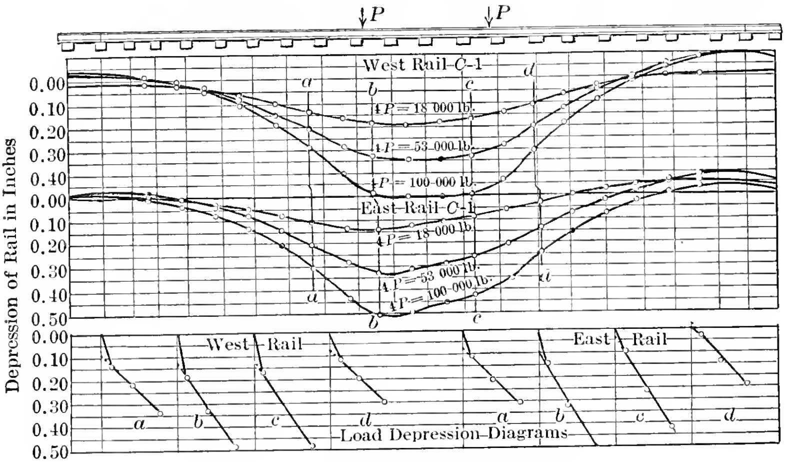


FIG. 32.—TRACK DEPRESSION PROFILES ON ILLINOIS CENTRAL RAILROAD.

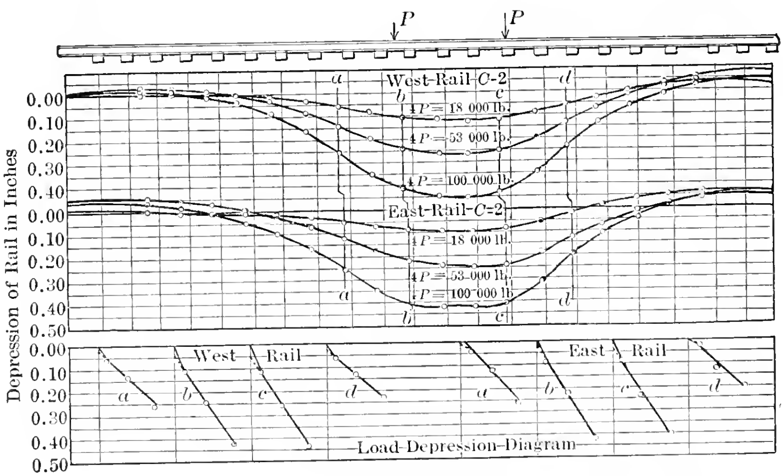


FIG. 33.—TRACK DEPRESSION PROFILES ON ILLINOIS CENTRAL RAILROAD.

the truck, and at a point midway between wheels the tie reaction may be $1\frac{1}{2}$% more. The value derived by means of track-depression formulas found by the analysis given in the first progress report for the conditions of this test is about 15% at the wheel and 16% midway between

wheels. The depression away from the wheels also agrees fairly well with that determined by the analysis. Still farther away, in the region where negative pressures have more influence in the analysis, it cannot be expected that the conditions of the track will be those assumed in the analysis.

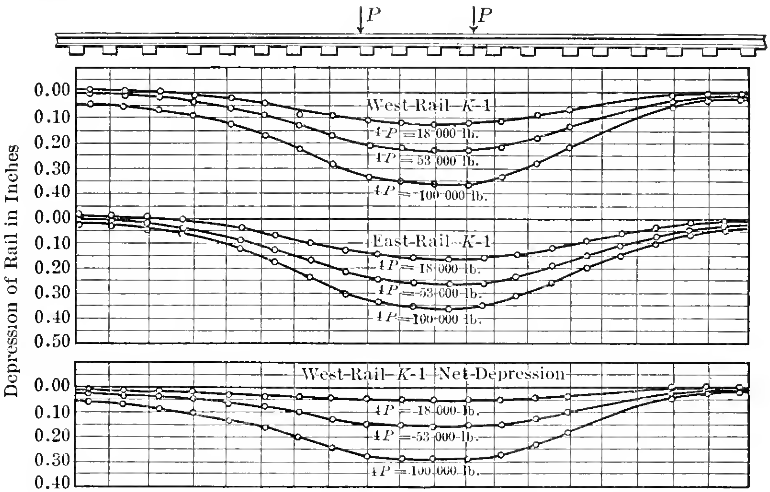


FIG. 34.—TRACK DEPRESSION PROFILES ON ILLINOIS CENTRAL RAILROAD.

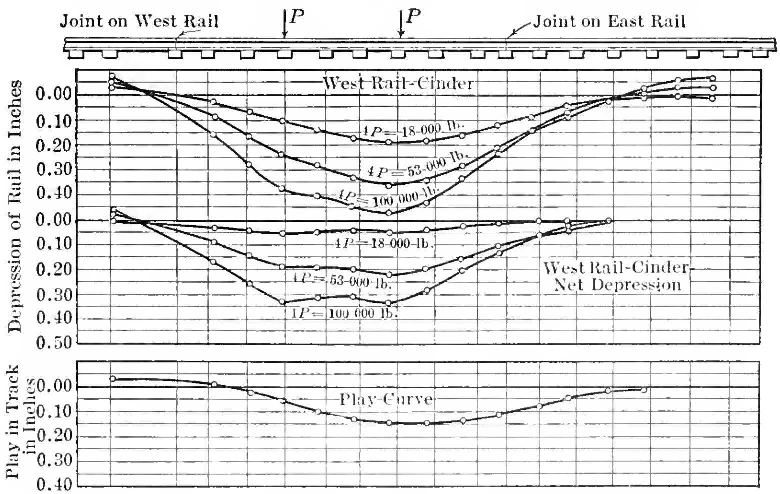


FIG. 35.—TRACK DEPRESSION PROFILES ON ILLINOIS CENTRAL RAILROAD.

The values at and between loads given in Table 13 are somewhat greater for a truck load of 53 000 lb. than for 100 000 lb., although the difference in ratios is not large. For the axle load of 18 000 lb. the ratio for the maximum tie reactions is still somewhat greater. If the partial

resistance corresponding to the first part of the depression of the track is taken into consideration, the difference in the ratios corresponding to the three loads will become still less. For most purposes it is sufficient to consider that the proportion of load taken by a tie is independent of the total load applied.

TABLE 13.—TIE REACTIONS IN TERMS OF LOAD ON TRUCK. ILLINOIS CENTRAL RAILROAD.

Location of Tests	Wt. of Rail Lb. per Yd.	Size of Tie in Inches	Depth of Ballast										
				Total Load = 53 000 lb.									
B-1	85	6 x 8	12 in.		0.02	0.07	0.11	0.14	0.16	0.16	0.14	0.12	0.08
B-2	85	6 x 8	12 in.		0.01	0.08	0.15	0.17	0.18	0.18	0.15	0.08	0.00
B-2	85	6 x 8	12 in.		0.02	0.09	0.16	0.19	0.18	0.17	0.13	0.06	0.00
C-1	85	6 x 8	6 in.		0.05	0.11	0.17	0.18	0.17	0.15	0.11	0.05	0.01
C-2	85	6 x 8	6 in.		0.04	0.08	0.12	0.15	0.16	0.16	0.14	0.10	0.05
				Total Load = 53 000 lb.									
K	125	6 x 8	24 in.	0.00	0.00	0.00	0.13	0.14	0.15	0.15	0.14	0.10	0.06
Cinder	85	6 x 8		0.00	0.00	0.04	0.10	0.15	0.19	0.21	0.17	0.09	0.05
				Total Load = 100 000 lb.									
B-1	85	6 x 8	12 in.		0.03	0.07	0.11	0.14	0.15	0.15	0.14	0.12	0.09
B-2	85	6 x 8	12 in.		0.03	0.08	0.14	0.17	0.17	0.17	0.14	0.08	0.02
B-2	85	6 x 8	12 in.		0.05	0.10	0.14	0.16	0.16	0.15	0.13	0.08	0.03
C-1	85	6 x 8	12 in.		0.06	0.10	0.16	0.17	0.16	0.15	0.12	0.05	0.02
C-2	85	6 x 8	12 in.		0.06	0.10	0.13	0.14	0.15	0.15	0.13	0.09	0.05
				Total Load = 100 000 lb.									
K	125	6 x 8	24 in.	0.03	0.06	0.10	0.12	0.14	0.14	0.14	0.12	0.09	0.06
Cinder	85	6 x 8		0.00	0.00	0.09	0.14	0.16	0.17	0.18	0.15	0.07	0.03

As would be expected, the stiffer rail at Location *K* gives a wider distribution of load and a smaller maximum tie reaction. By the analysis for the conditions of the test, the reaction of the tie at a wheel is calculated to be 13% of the load on the truck. The depression profiles for this location are regular, and nearly the same for the two rails, as

might be expected with the stiffer track. On the other hand, the depression profiles for the freight track (cinder ballast) are irregular and uneven, the load-depression curves deviate considerably from a straight line, and the conditions are such as to give uneven loads on ties and to increase the stress in rail over that which would be found in good track.

The amount of the play between rail and tie and tie and ballast shown by the load-depression diagrams ranged from 0.06 to 0.18 in. (untamped track). On some of the sections, the amount varied considerably throughout the length carrying the load, say, 0 to 0.10 in., showing a great diversity in the bearing of the several ties. The condition of the bearing at the two sides of the track also differed considerably. These facts will be found to be significant when the discussion of the flexure of ties is made. It is true, of course, that in places away from the test sections, which had ties of uniform dimension and spacing, the track play was greater and more variable, as could be observed at the time trains were passing.

The values of u, the modulus of elasticity of rail-support, obtained from the test data for Locations B and C, range from 900 to 1 300 lb. per in. per in., with an average value of 1 100. The value at Location B-2, after the track had been tamped slightly, was about 1 200. The value at Location K (24 in. of ballast not recently tamped) was about 1 200. The value for the test on cinder ballast was 1 000, although it must be borne in mind here again that this track was not in good surface.

20.—Track Depression Tests on Chicago, Milwaukee and St. Paul Railway.—The tests for track depression on the Chicago, Milwaukee and St. Paul Railway were made in the manner already described for the tests on the Illinois Central Railroad. The loads on the truck at one end of a car were 100 000, 68 000, and 37 000 lb., which were assumed to be equally divided among the four wheels of the truck. The wheel base of the truck was 5 ft. 6 in., and the distance center to center of trucks was 28 ft. 10 in., 29 ft., and 25 ft. 11 in., respectively, for the cars giving the loads named above. As the rails were laid with alternate joints, the center of the trucks was placed at the quarter points of the rail.

The tests were made on the main line of the Milwaukee Division and on the Janesville Division, a branch line. The tests on the main line were made at two points (see Fig. 36), Q on the east-bound main track about a mile south of the station at Deerfield, Ill., (east in railroad parlance) and O and P on the east-bound main track a quarter of a mile nearer the station. In each case passing tracks permitted traffic to be routed so that the tests were not interfered with. The tests on the Janesville Division were made on the single track a mile west of the station at Libertyville, Ill.

On the main-line track at Deerfield (called by the Railroad Company Class A track) the rail was 100-lb. Am. Soc. C. E. section. The ties were mostly hewn red oak ties, zinc-chloride treated, though perhaps 20% were sawed ties which had replaced old ties. The hewn ties were variable in width ranging from 8 to 11 in.; the sawed ties were 8 in. wide. Part were 7 in. thick and 8 ft. 6 in. long and part 6 in. thick and 8 ft. long. The ties were spaced about 20 in. center to center (twenty to a rail length of 33 ft.). The spacing was fairly uniform. The ballast was bank-run gravel, 45% of which passes a ¼-in. sieve. The depth of ballast was about 36 in. At the side next the other main track, and also on the other side of Location *Q*, the surface of the ballast ran level from top of tie of track tested to top of the tie of the adjacent track. At Location *O* and *P*, on the outer side the ballast extended at level of the tie for a distance of 15 in. from the end of the tie and then sloped down 10 in.

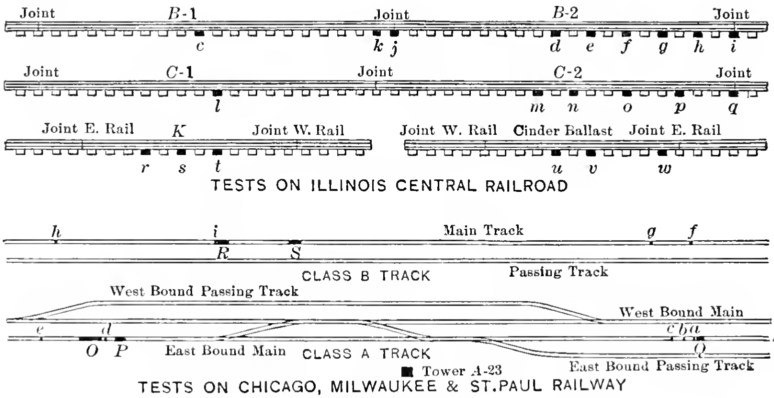


Fig. 36.—Location of Track Depression Tests and of Tie Flexure Tests.

in 2 ft. (see Fig. 44), so that in all cases there was adequate opportunity for full support at the end of the tie. The track surface was in good condition, but it had not been tamped for some months. The roadbed at Location *Q* was not much above the level of the ground; Location *O* and *P* was on an embankment of considerable age.

On the branch-line track at Libertyville (called by the Railroad Company Class B track) the rail was 75-lb. Am. Soc. C. E., section. The ties were mostly hewn soft wood ties, quite irregular in shape, but 20% were sawed ties, both oak and soft wood. The sawed ties were 6 by 8 in. by 8 ft., and the hewn ties were somewhat wider. The ties were spaced twenty to a rail length of 33 feet. The ballast was gravel about 36 in. deep. Due to the existence of the passing track (see Figs. 36 and 44) there was little slope on one side of the track. On the other the ballast sloped from 3 in. below the top of tie at its end at a 1:2 slope, forming a less effective support than was found on the other side. The

track surface was in indifferent condition, the track not having been tamped for some time. At places this track had been built over soft spots, which at times had given trouble by subsidence.

Fig. 37 gives the track-depression profiles at Locations *Q* and *P* of Class A track and Fig. 38 at Location *O*. In the figures load-depression diagrams at several points of these profiles are also given. The play in track denoted by the intercept at the vertical axis, found as shown in Fig. 30, was determined for a number of points along the rail; in Fig. 37 (and also in Figs. 39 and 40) a second set of profiles for one test has been drawn by plotting the net depressions found by deducting from the measured depression the play so determined. It will be noted that the profile of measured depressions is somewhat irregular and unsymmetrical. The profile of net depressions is more nearly regular and symmetrical, and the final load-depression ratio shows nearly the same stiffness throughout. This illustrates the variations in tie-bearing at points close together even in good track in fair condition; it has significance in relation to bearing pressure of tie, tamping conditions, and stress developed in the rail. The amount of the track play ranges from 0.02 to 0.17 in. in the track-depression profile of Figs. 37 and 38. In these tests, also, the depressions for one rail differed considerably from those for the other, though the net depressions were in close agreement.

Figs. 39 and 40 give the track-depression profiles on Class B track and also load-depression diagrams for several points along the rail for these tests. This track shows more irregularity along the length of the rail and more variation in play than was found in Class A track. At the point of maximum depression on the west rail of the upper profile of Fig. 39 the tie had been cut into by the tie plate about $\frac{1}{2}$ in., a fact which was brought out when the load was applied.

In Table 14 the tie reactions are given for the several tests on the Chicago, Milwaukee and St. Paul Railway, the values being in terms of the load on one truck. The values at and between wheels range from 10 to 15%. Class A with the heavier rail has a somewhat lower tie reaction than Class B.

The value of *u*, the modulus of elasticity of rail-support obtained from the track-depression profiles, is about 2 000 lb. per in. per in. for class A track, and 900 for Class B track. The value for Class A track is materially higher than that found in the Illinois Central tests. Several factors may contribute to this—longer ties, broader ties (more bearing area in a rail length), gravel ballast instead of limestone ballast, greater depth of ballast, or better supporting conditions at ends of ties.

IV.—Depression, Flexure, and Bearing Pressure of Cross-Ties.

21.—The Cross-Tie and its Action under Load.—In railroad track of ordinary construction the cross-tie performs many important func-

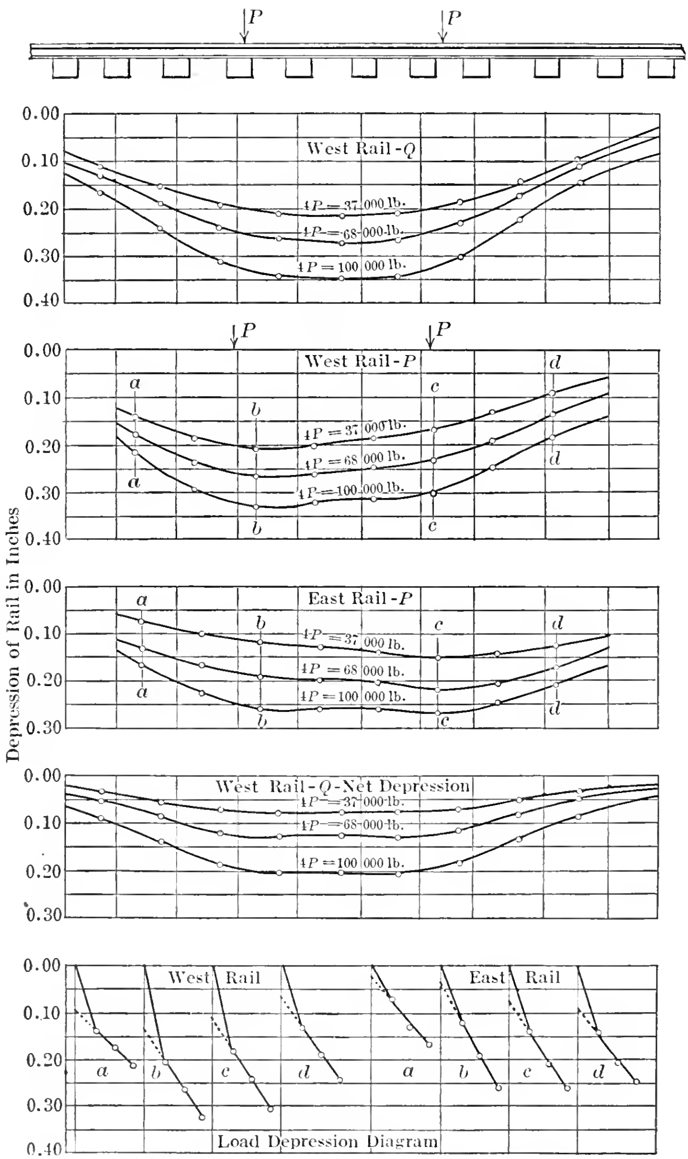


FIG. 37.—TRACK DEPRESSION PROFILES ON CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY: CLASS A TRACK.

tions—it bears the load transmitted from the rails, makes a definite connection and spacing between the two lines of rails, transmits the pressure to the bed of ballast and by its properties as a beam distributes this pressure along its length. It thus is subject to compression under and in the vicinity of the rail, to tension or compression as a structural connection between rails, and to beam action in giving distribution to bearing pressures along its bed. Of these the last bears the most important relation to the problems here considered; the others will not be treated at this time.

The cross-tie has many features which make it an acceptable part of ordinary track construction. It has great flexibility in meeting the

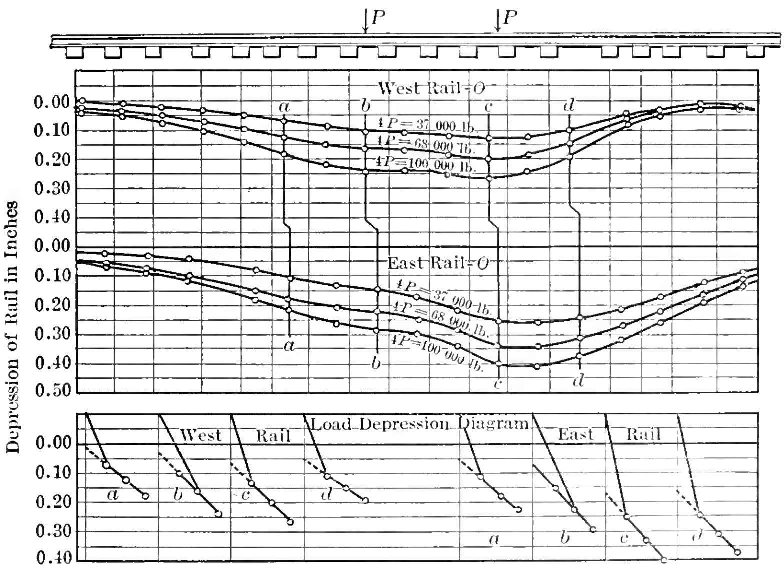


FIG. 38.—TRACK DEPRESSION PROFILES ON CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY: CLASS A TRACK.

varied and diverse requirements of both ordinary and unexpected track and load conditions. It gives facility in providing, maintaining, or shifting the gauge, line and surface of track and in tie renewals and other changes in track, and is accepted as an economical and reliable element of ordinary track construction. It is known to be effective under very imperfect track conditions, being used where great variation of size and quality of tie, depth and quality of ballast, and condition of tamping of track may be expected to cause marked differences in the requirements put upon it. Quantitative data on the flexural action of the tie and the way its loads are distributed along its bed, as well as of its depressions under load, therefore should be of considerable value.

22.—Method of Attacking the Problem.—The problem to be considered relating to the action of the tie involves the distribution and intensity of the bearing pressure on its bed along its length and also the bending moments and stresses developed by this pressure and the load applied through the rails—these to be determined for the limits and ranges of values included in the variety of conditions to be found in track. This information will throw light on the question of the intensity of pressure on the ballast and also on the design of the tie, particularly if a tie of new form or dimensions or of materials other than wood were to be considered. The question of the intensity of pressure on the ballast for differing conditions of track tamping or of

TABLE 14.—TIE REACTIONS IN TERMS OF LOAD ON TRUCK.
CHICAGO, MILWAUKEE & ST. PAUL RAILWAY.

Location of Tests	Wt. of Rail Lb. per Yd.	Size of Tie in Inches	Depth of Ballast	Load on Truck = 68 000 lb.									
O	100	7 x 8	36 in.	0.08	0.09	0.10	0.11	0.11	0.10	0.11	0.11	0.10	0.07
P	100	7 x 8	36 in.	0.04	0.08	0.11	0.13	0.13	0.13	0.12	0.12	0.09	0.05
Q	100	7 x 8	36 in.	0.03	0.07	0.11	0.15	0.15	0.15	0.14	0.11	0.07	0.02
R	75	6 x 8	36 in.	0.06	0.08	0.10	0.10	0.10	0.11	0.14	0.13	0.10	0.07
S	75	6 x 8	36 in.	0.06	0.09	0.13	0.14	0.13	0.13	0.12	0.10	0.06	0.03
				Load on Truck = 100 000 lb.									
O	100	7 x 8	36 in.	0.07	0.09	0.10	0.11	0.11	0.11	0.11	0.12	0.10	0.08
P	100	7 x 8	36 in.	0.04	0.08	0.11	0.13	0.13	0.13	0.13	0.11	0.09	0.05
Q	100	7 x 8	36 in.	0.04	0.07	0.11	0.14	0.14	0.14	0.13	0.11	0.08	0.03
R	75	7 x 8	36 in.	0.07	0.09	0.11	0.11	0.10	0.11	0.14	0.12	0.08	0.05
S	75	7 x 8	36 in.	0.06	0.09	0.13	0.14	0.13	0.13	0.12	0.10	0.06	0.03

track maintenance has a bearing on the questions relating to track ballasting. Even bearing pressures give good riding quality to the track, while spots with less and greater resistance to depression increase the stress in the rail and other parts of the structure and cause more rapid deterioration in the quality of the track. The determination of bending moments and stresses is closely related to various other parts of the problem.

A study of methods which may be used in attacking the problem of determining the distribution of the bearing pressure along the length of the tie will bring out the difficulties attending the experimental work. There is a great diversity of variations—differences in bearing pres-

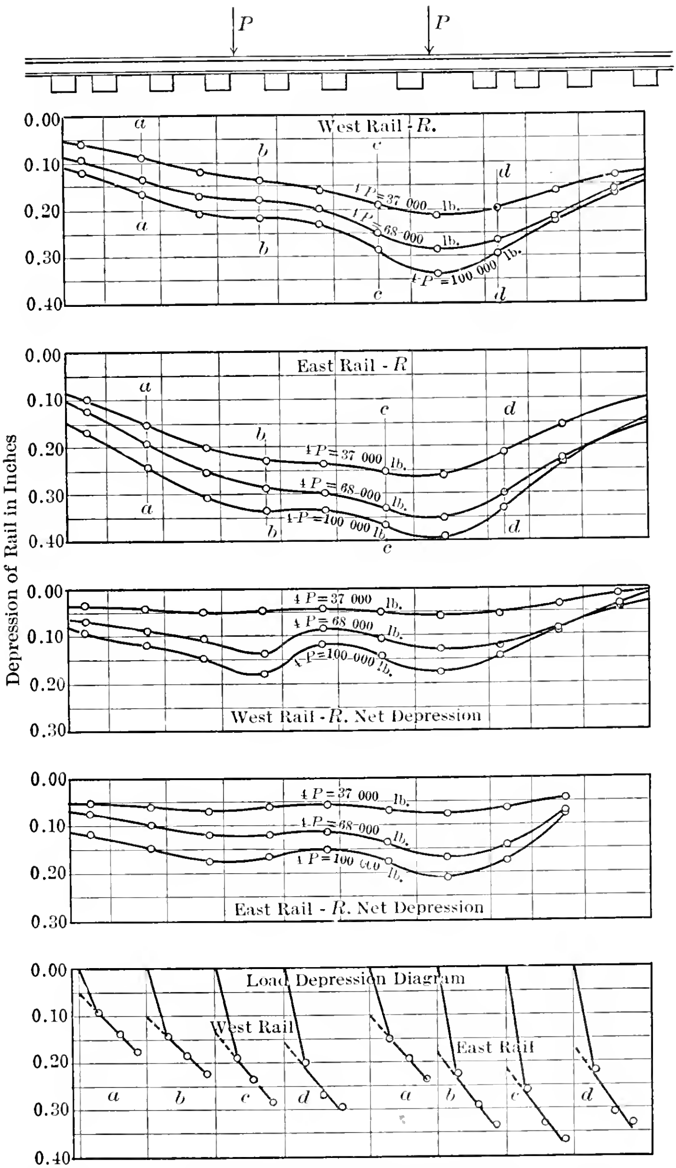


FIG. 39.—TRACK DEPRESSION PROFILES ON CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY: CLASS B TRACK.

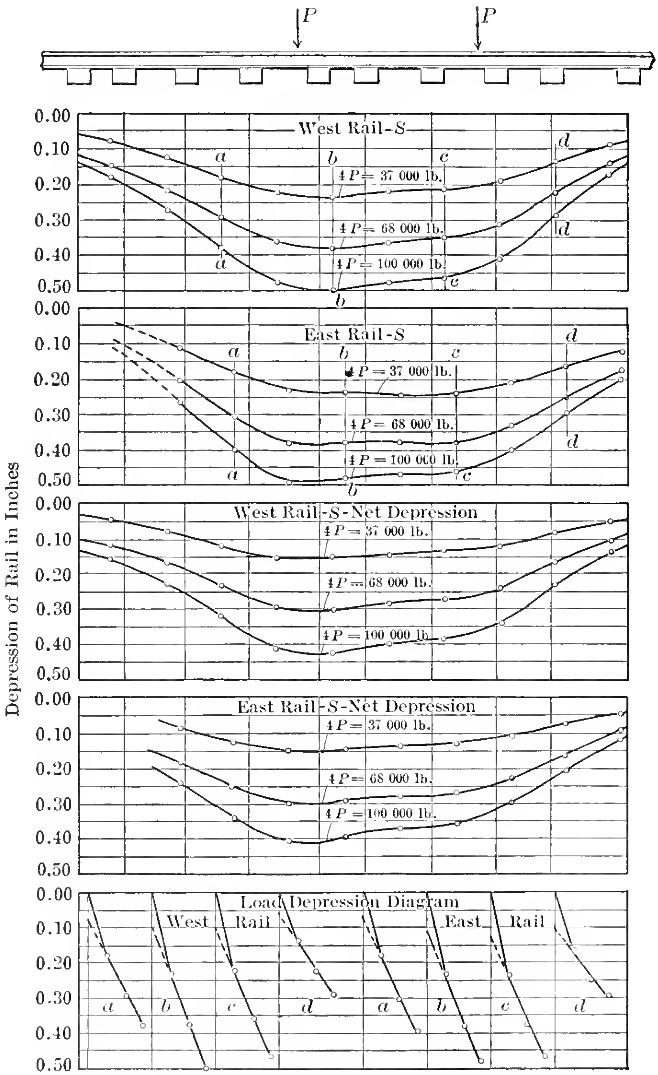


FIG. 40.—TRACK DEPRESSION PROFILES ON CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY: CLASS B TRACK.

sures across the width of the tie and along the tie; play between tie and its bed, which varies in different parts of the length of the tie and varies greatly with the nature of the tamping and the effects of the action of traffic; unequal stiffness (yieldability) of the ballast at various points—these illustrate difficulties encountered in the problem. The use of pressure-measuring devices between tie and ballast—such as the pressure capsule described in the first progress report—gave general information and served fairly well in the laboratory investigation; but the number required in the length of one tie to give the needed information and large number of ties required to determine the run of conditions, the disturbance of the track through inserting the instruments with the uncertainty as to whether the resulting condition of track was representative of normal track, and the chance for instruments becoming deranged in the interval elapsing until the track would seem to have reached normal conditions, all combined to make the direct measurement of bearing pressure impracticable as a method of getting the information desired on this subject. Of indirect methods the measurement of the strains or deformations along the length of the tie as produced by its bending was considered, but variations in the properties of the wood, especially under field conditions, as well as uncertainties of other kinds, rendered this method impracticable.

A trial was then made of a method of measuring the curve of flexure of the tie as it bends under the applied load in the track and making use of the relations between flexure, bending moment, and load as derived by mechanics of materials for a beam having the properties of the timber tie used. The measurements made included also the depression of the tie below its original position, as produced by the compression of the ballast and roadway or other conditions. This method is manifestly imperfect, having a number of limitations and uncertainties, but it is not difficult to use, the track conditions may be taken as they are found, and the number of tests may be chosen to cover a variety of conditions of ties and track. The measurement of tie depressions also gives information of value in the study of stresses in track. The method was used therefore as being the best known method applicable to the conditions of the track tests. It has given data of value, although certain uncertainties and inconsistencies are discernible in the results, especially those resulting from the local bearing compression in the vicinity of the rail. The details of the method will be described in the following article. The consideration of the bending moments will be given in a succeeding article. Here it is only necessary to note that the curvature of the curve of flexure of the beam at any point is proportional to the corresponding moment and stress—the sharper the curve the greater the moment and the stress.

23.—Method of Making Tests.—In measuring the depression and flexure of the ties a stiff wooden reference bar (see Figs. 41 and 42) was placed under the rails between ties and close to the one on which measurements were taken. At each end of this bar was attached an iron cross-bar about 2 ft. long, the ends of which rested on two substantial stakes well driven into the ground, giving a firm support to the apparatus. These stakes were 7 ft. or more from the center of the track. Attached to the main bar were iron brackets (shown in Fig. 41) which projected over the tie. To each bracket was attached a piece of small angle iron; on this was bolted an Ames dial gauge which reacted against a tack driven at the mid-point of the width of the tie and served to measure the depression of the tie at that point. The arrangement of the attachment permitted adjustments vertically and horizontally.

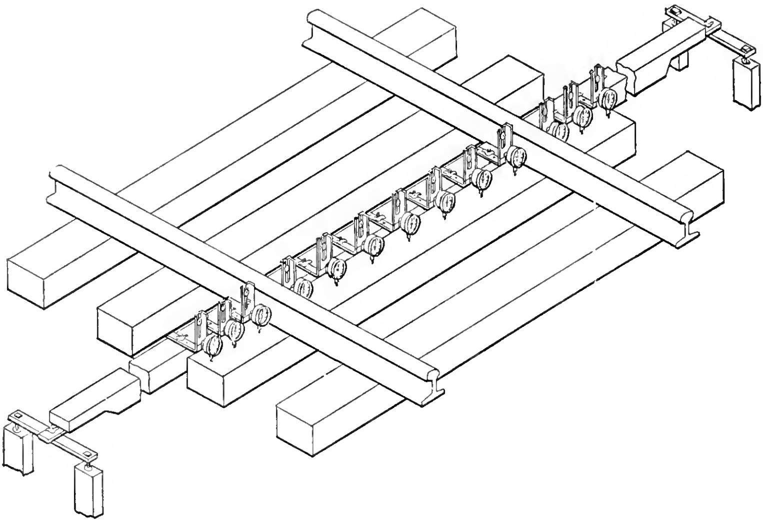


FIG. 41.—REFERENCE BAR FOR TEST OF DEPRESSION AND FLEXURE OF TIE.

Before applying a load the dials were adjusted to read zero. For each load applied the dials were read to the nearest half-thousandth of an inch. When the load was removed, a small depression was indicated by the dials and they were again set at zero. The same load was again applied, the process being continued until three consistent sets of readings were obtained. The average of these sets of readings was used.

In the tests on the Illinois Central Railroad nine dial gauges were used—five between rails and two on the outer side of each rail. This number of points was found not to determine the curve of flexure as accurately as was desired, and in the later tests made on the Chicago, Milwaukee and St. Paul Railway the number of dials was increased to thirteen, seven between rails and three on the outer side of each rail; this

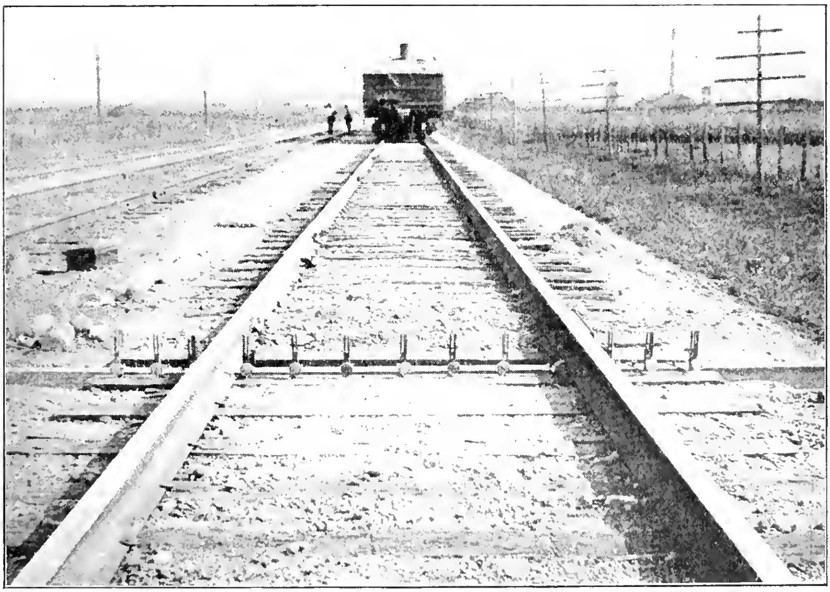


FIG. 42.—REFERENCE BAR FOR TEST OF DEPRESSION AND FLEXURE OF TIE.

improved the character of the data very much. In each case the dials next the rails were 1 to 2 in. away from the base.

The loads were given by means of loaded cars, as already described for the tests of track depression. The three loads on a single truck (two axles) were 18 000, 53 000, and 100 000 lb. on the Illinois Central Railroad and 37 000, 68 000, and 100 000 lb. on the Chicago, Milwaukee and St. Paul Railway. The leading wheels of the truck carrying the load were placed directly over the tie under test. The amount of the load considered to bear on the tie under test was taken from the results of the track-depression tests at the given location. The smallest load used was generally more than sufficient to overcome the play between tie and ballast, though of course this should not be taken to mean that under this condition the pressure on the bed of ballast is distributed uniformly along the length of the tie. The largest load used gave a tie reaction considerably less than that which would be caused at and between drivers by an ordinary Mikado or Santa Fe type locomotive. In the study of the data the largest load was generally used, though the smaller loads have given valuable information on the action of the tie.

The readings in all the tests checked very closely and the results are concordant. The effect of the rail bearing in compressing the fibers adjacent to the rail is unknown, but the reading of the dials next to the rail must include the general depression and bending of the tie and also a third element—the influence of the local downward compression of the tie due to the bearing pressure of the rail; the latter will have to be taken into account in interpreting the curves of flexure as related to bending moments and stresses.

The form of reference bar given in Fig. 41 is the improved form used in the tests on the Chicago, Milwaukee and St. Paul Railway. The bar used in the earlier tests was lighter and less stiff. In the use of this apparatus it should be noted that it was necessary to remove the ballast between the tie to be tested and an adjoining tie to a depth of 4 or 5 in. below the top of tie. This probably had little effect upon the action of the tie during the tests, although under continued traffic of no greater loads the effect might be noticeable.

24.—Location and Description of Track.—Fig. 36 gives data on the location of ties at which measurements of depression and flexure were made, together with condition of the track. The letters *B*, *C*, and *K* designating location on the Illinois Central Railroad refer to the sections of track north of Champaign, Ill., shown in Fig. 26 of the first progress report. The ties on the main-line track were the sawed oak ties (6 by 8 in. by 8 ft.) furnished for the test track in 1914. The tests on the freight lead were made on two hewn oak ties about 6¼ by 8¾ in. by 8 ft. and a sawed oak tie 6 by 8 in. by 8 ft. The location of the tests on the Chicago, Milwaukee and St. Paul Railway has already been described under "Track Depression Tests on the Chicago, Milwaukee

and St. Paul Railway". Sawed ties were selected for test because of their uniformity of cross-section. The ties on Class A track were 7 by 8 in. by 8 ft. 6 in.; those on Class B track 6 by 8 in. by 8 ft. Tie plates 8 by 9 in. were on all ties in the Class B track.

Attention should be called to the condition of the cross-section of track at the test locations given in Figs. 43 and 44. In some of the sections on the Illinois Central Railroad it may be seen that there is a scant amount of ballast above the bottom of the tie near its ends, particularly on the outer side of the track. On the Chicago, Milwaukee and St. Paul Railway, as has already been pointed out, the sections are such that there was opportunity for full support at the end of the tie. The condition of the track surface has been described under "Track Depressions"; it may be well again to call attention to the fact that the track in all the test locations had not received a general tamping for some time and that in some locations it was apparent that the track was in indifferent condition as to surface and tamping, and thus furnished opportunity to determine depressions and flexure under other than best conditions, and really under conditions frequently found in practice.

25.—Diagrams of Depression and Flexure and Their Significance.—Figs. 45 to 54 give the depressions and flexure of the individual ties at a truck load of 100 000 lb. The load on a single tie, as determined by the track-depression profiles, ranged from 11 000 to 18 000 lb.; perhaps averaging 15 000 lb. The vertical scale is relatively large, thus bringing out the curvature, which of course is slight, as is the case with any short stiff beam. The tie depression under this load varies from 0.35 to 0.5 in. Figs. 55 and 56 give composite diagrams of the flexure of several ties at the same location and which have the same general characteristics of flexure; the differences in depressions and the tilting of the ties are not here considered—the diagrams are plotted with reference to a line drawn from rail to rail. In Fig. 47 curves are drawn to represent the depressions and flexure for all three truck loads. The dotted lines given in this figure (and in the other figures), obtained by a method described farther on, are intended to represent the position of the ballast bed under the tie when there is no load on the tie; the dotted lines given are for the tie "before tamping".

An examination of the diagrams of depression and flexure brings out a variety of conditions. It will be observed that there is bending of tie in every case, though the form of the curve varies greatly. It is evident that there must be great differences in the way in which the bearing pressure varies along the length of the tie under the conditions to which ties are subjected. In many ties there is play between the tie and its bed at one point or another or even over a considerable portion of its length, which not only gives unevenness of track depression but increases the intensity of bearing pressure at some point along the tie

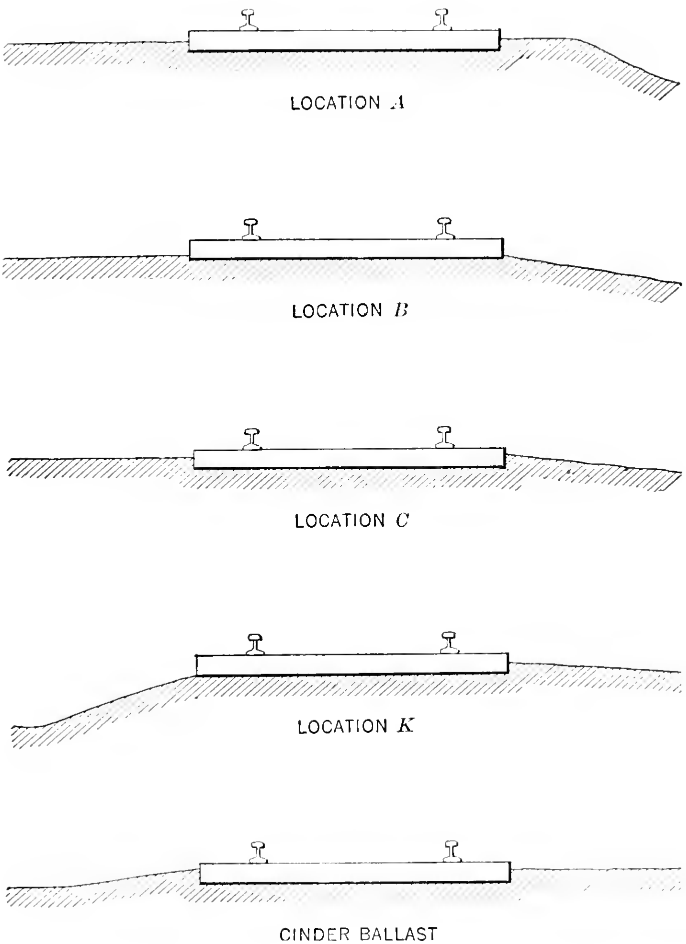


FIG. 43.—CROSS-SECTIONS OF TRACK ON ILLINOIS CENTRAL RAILROAD.

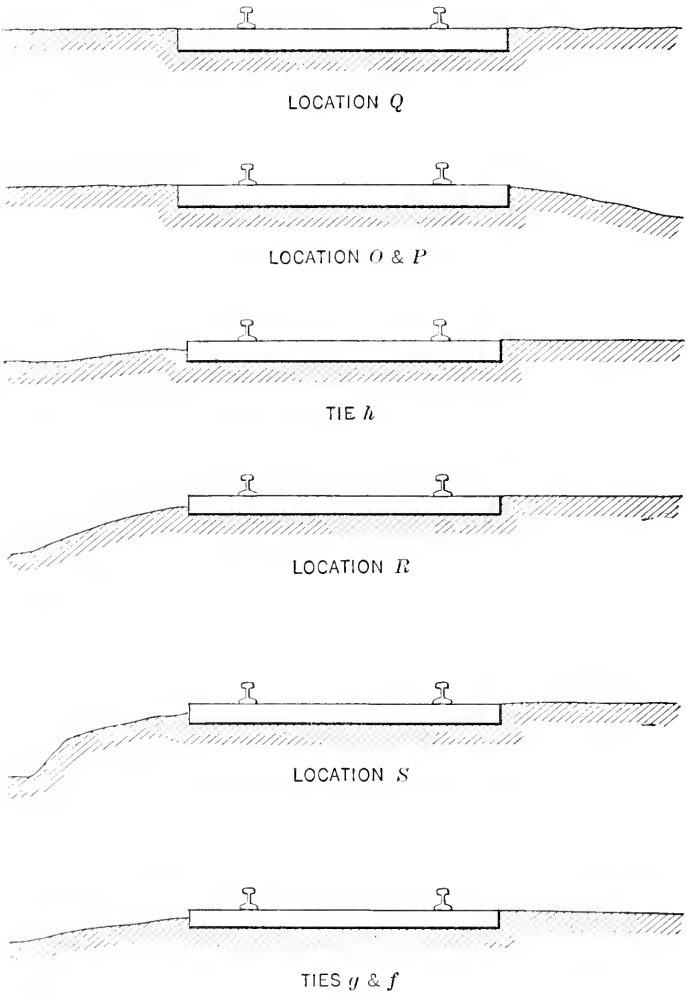


Fig. 44.—Cross-Sections of Track on Chicago, Milwaukee and St. Paul Railway.

and gives added bending stresses in the tie. It is clear that there is a great variety of distribution of bending moments along the tie—the bending moment at a section at the middle of the tie may be positive in one tie and negative in another, as is shown for Tie *o* in Fig. 50 for "after tamping" and "before tamping". Attention should be called to the fact that the tamping done was slight and at the ends of the tie only; the term "after tamping" should not be taken to mean a general tamping.

The conditions just referred to are ordinarily termed endbound and centerbound. It will appear that the latter condition is very common; in fact, the upward curvature at the middle and a large negative

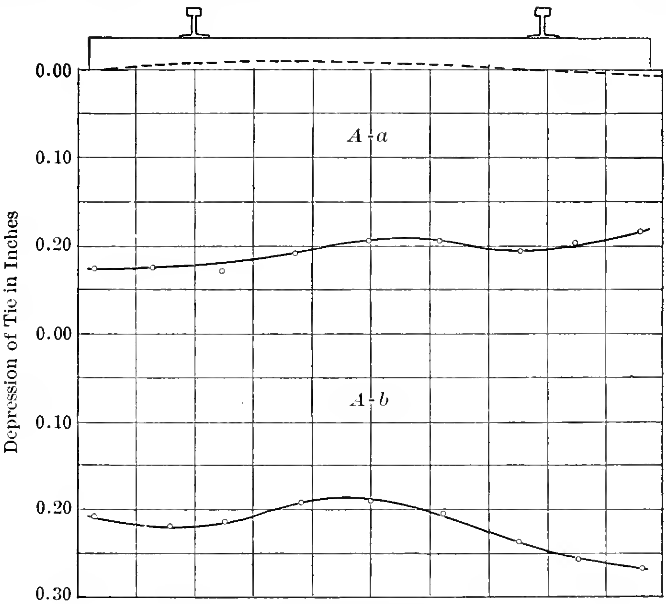


FIG. 45.—DIAGRAM OF DEPRESSION AND FLEXURE OF TIES, ILLINOIS CENTRAL RAILROAD.

moment accompanying it may be expected in most track after traffic has had its effect upon track condition. The immediate effect of tamping a tie in ballast already well compacted being to change the bearing conditions along the tie (the compacting of the ballast in the tamping having only a secondary effect), a fresh tamping or a change in the place of tamping makes a marked effect on the flexure of the tie. The ties in Location *B* were found to be loose at their ends under the conditions of the track in service, with a resulting flexure curve shown in Figs. 46, 47, and 48 for Ties *c* to *k*. The part of these ties outside the rails was then tamped slightly, not vigorously, and the curve in Fig. 49 for Tie *g* slightly tamped shows that the bearing is largely at the

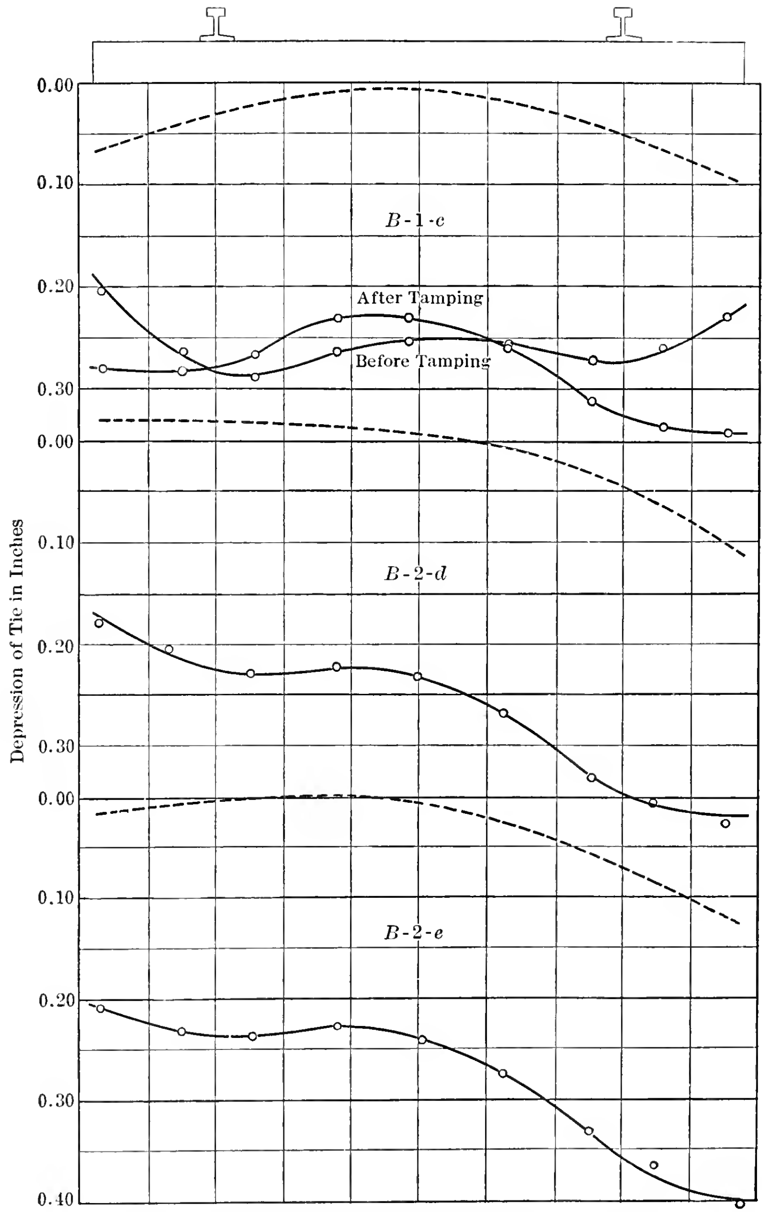


FIG. 46.—DIAGRAM OF DEPRESSION AND FLEXURE OF TIES, ILLINOIS CENTRAL RAILROAD.

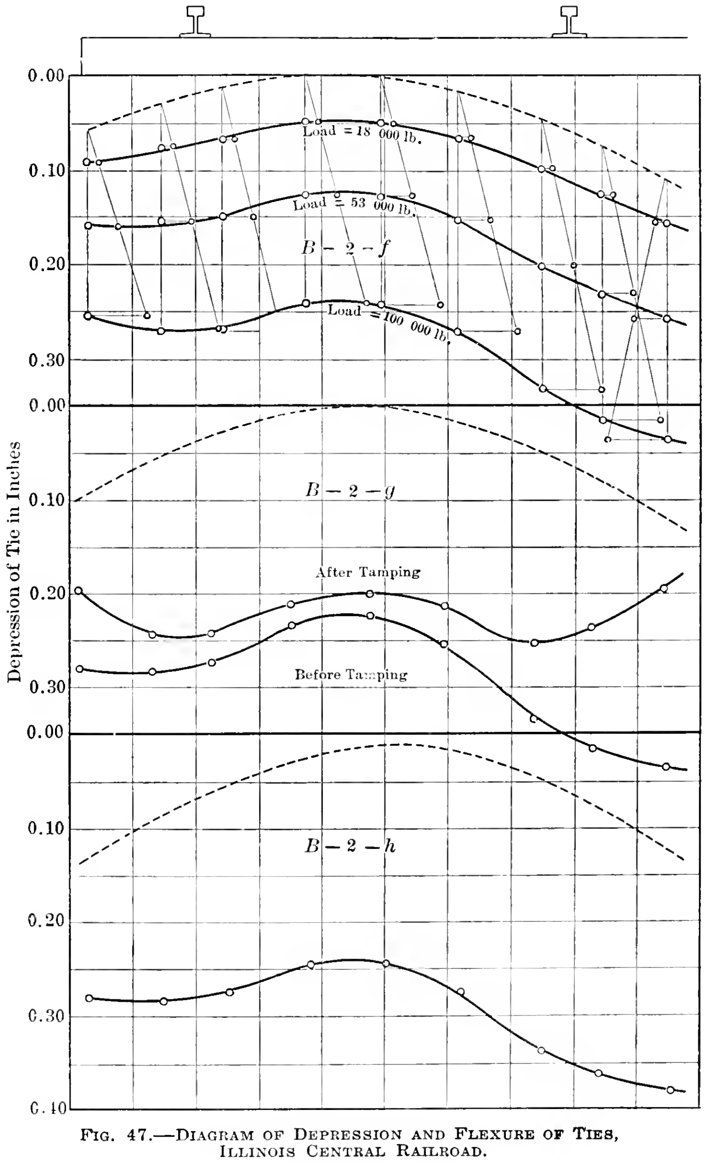


FIG. 47.—DIAGRAM OF DEPRESSION AND FLEXURE OF TIES, ILLINOIS CENTRAL RAILROAD.

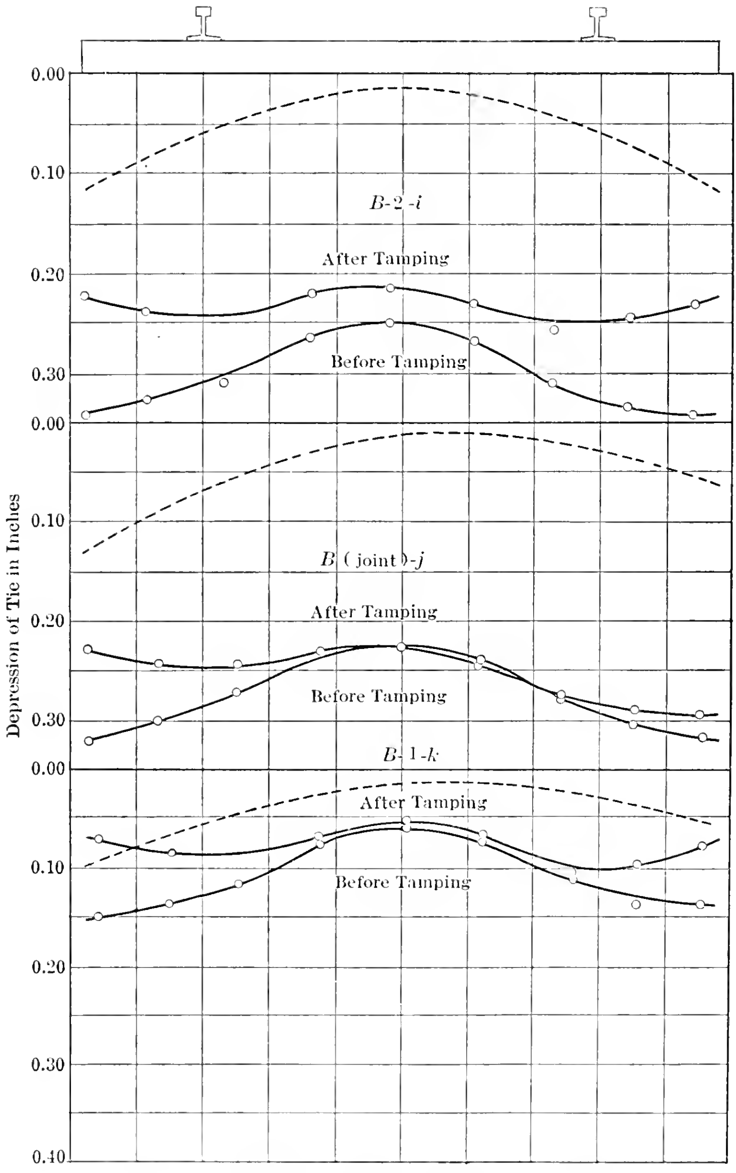


FIG. 48.—DIAGRAM OF DEPRESSION AND FLEXURE OF TIES, ILLINOIS CENTRAL RAILROAD.

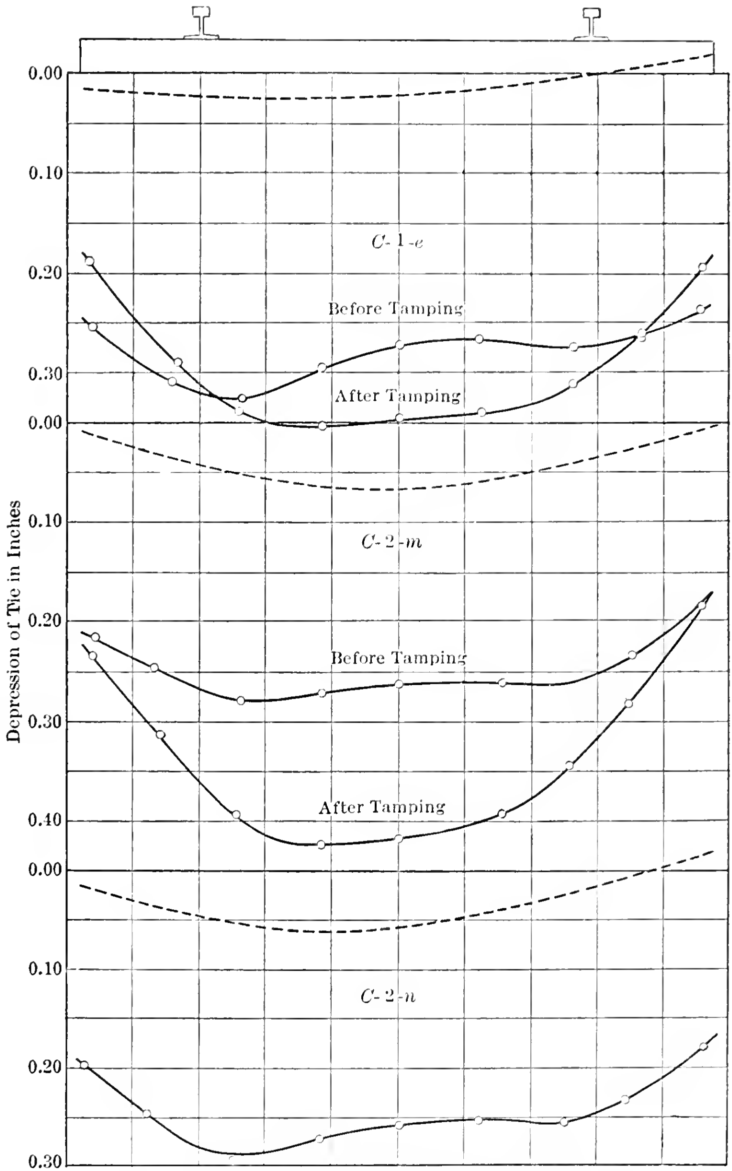


FIG. 49.—DIAGRAM OF DEPRESSION AND FLEXURE OF TIES, ILLINOIS CENTRAL RAILROAD.

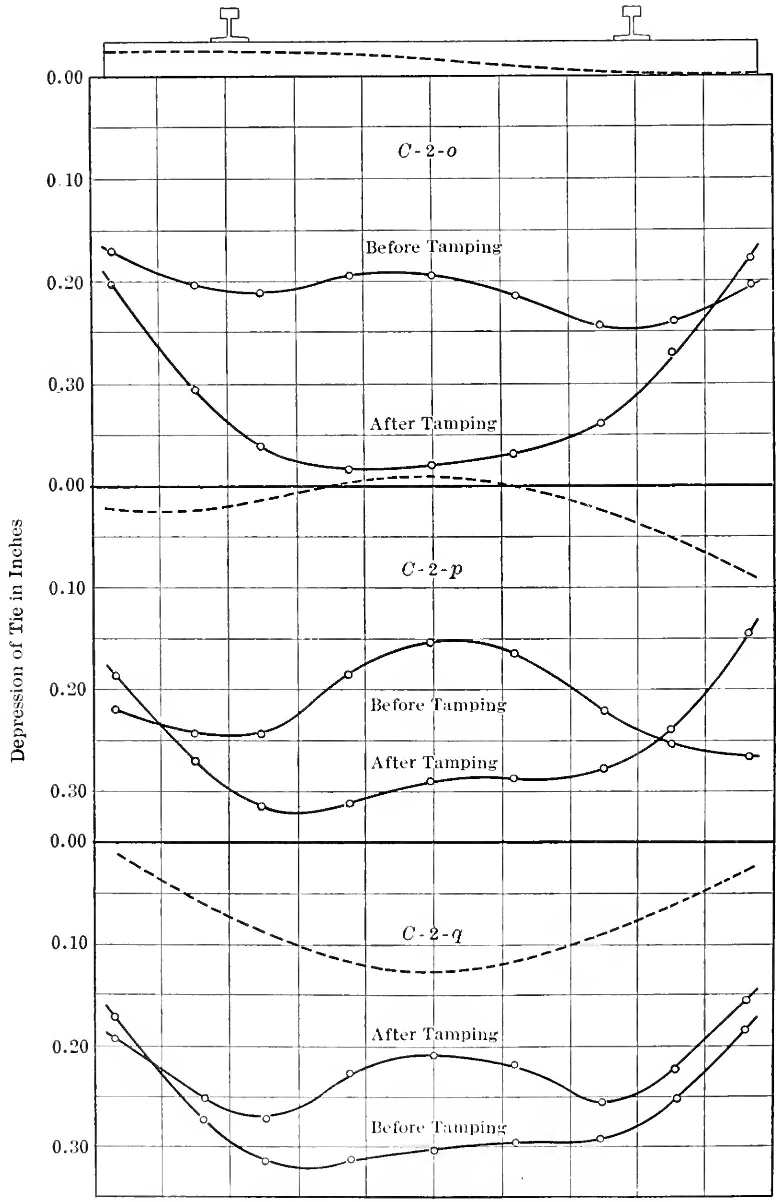


FIG 50.—DIAGRAM OF DEPRESSION AND FLEXURE OF TIES, ILLINOIS CENTRAL RAILROAD.

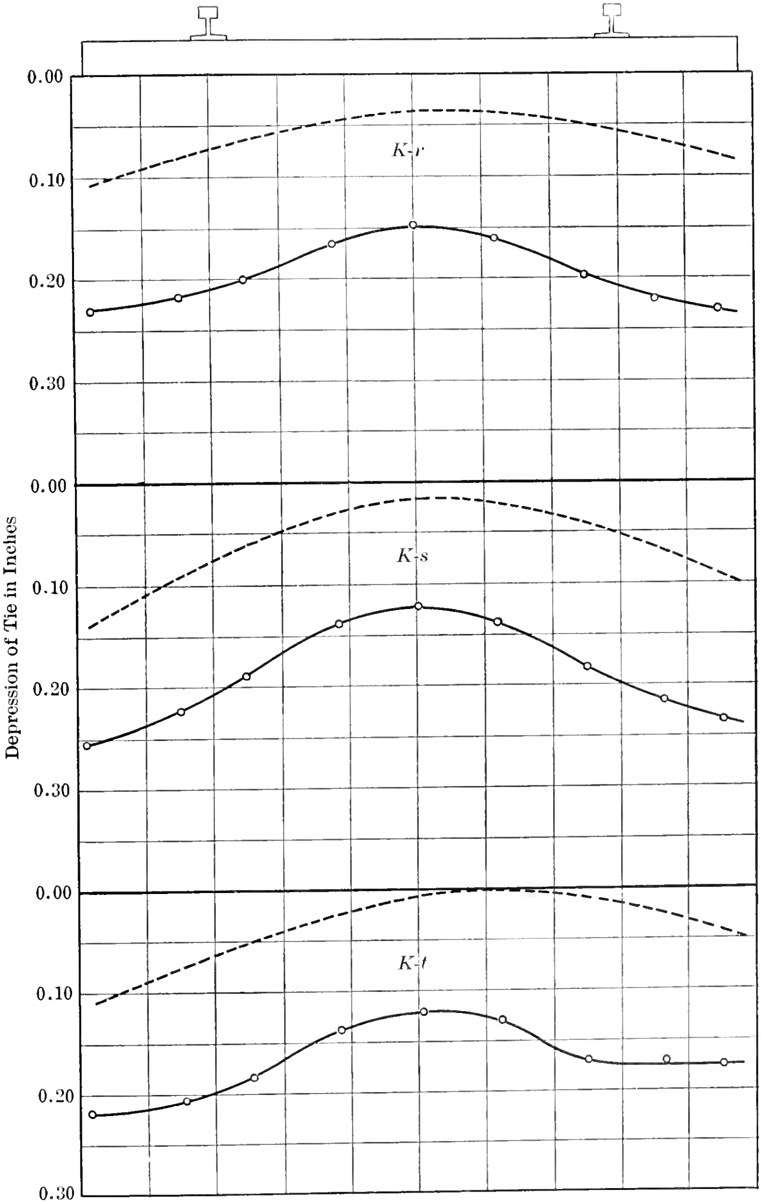


FIG. 51.—DIAGRAM OF DEPRESSION AND FLEXURE OF TIES, ILLINOIS CENTRAL RAILROAD.

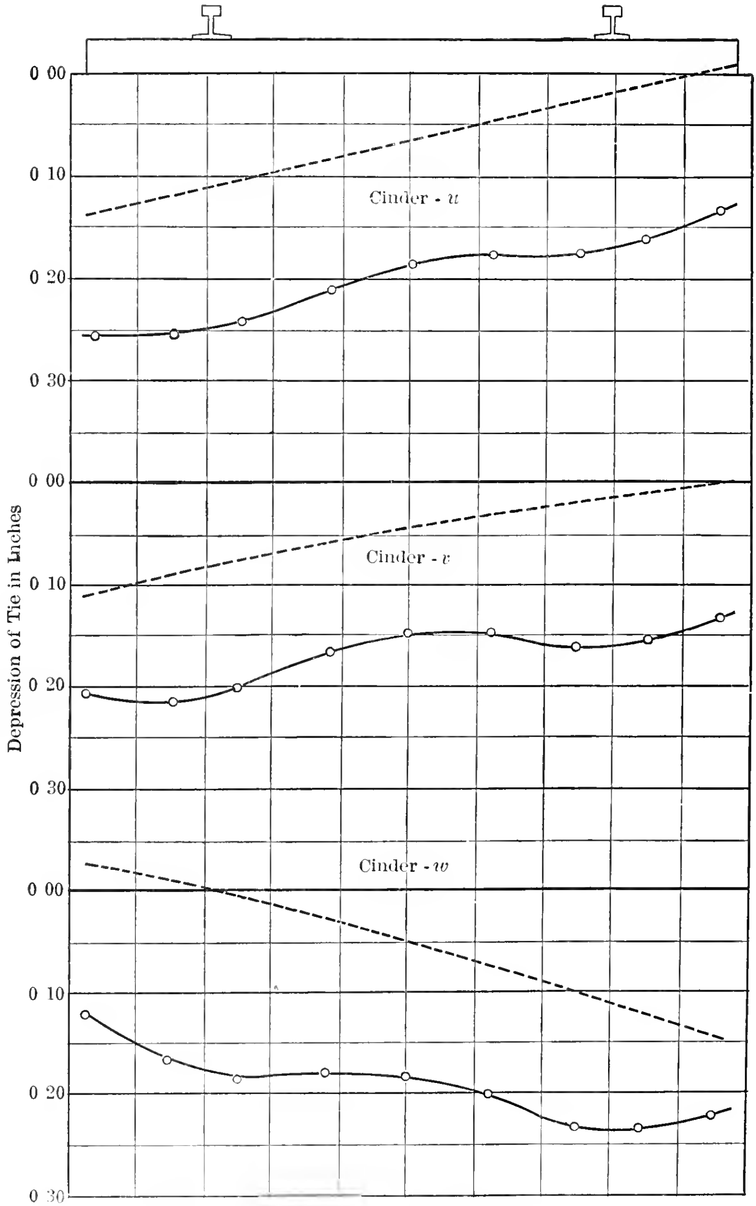


FIG. 52.—DIAGRAM OF DEPRESSION AND FLEXURE OF TIES, ILLINOIS CENTRAL RAILROAD.

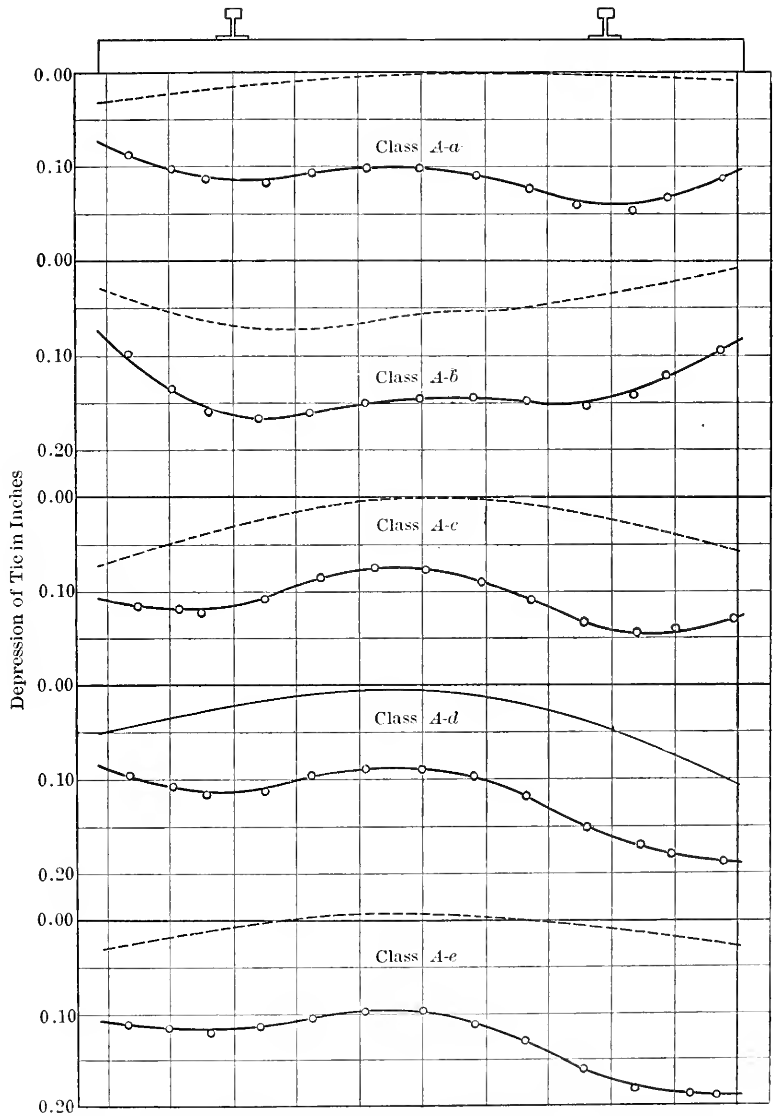


FIG. 53.—DIAGRAM OF DEPRESSION AND FLEXURE OF TIES, CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY.

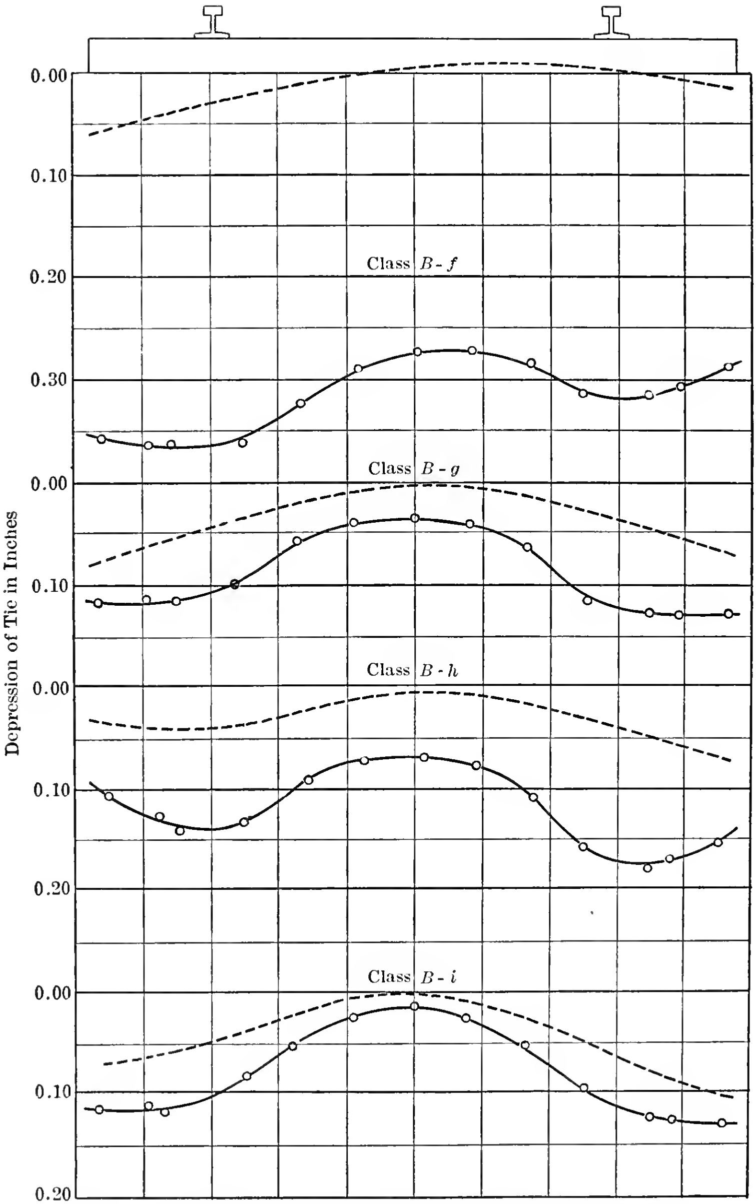


FIG. 54.—DIAGRAM OF DEPRESSION AND FLEXURE OF TIES, CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY.

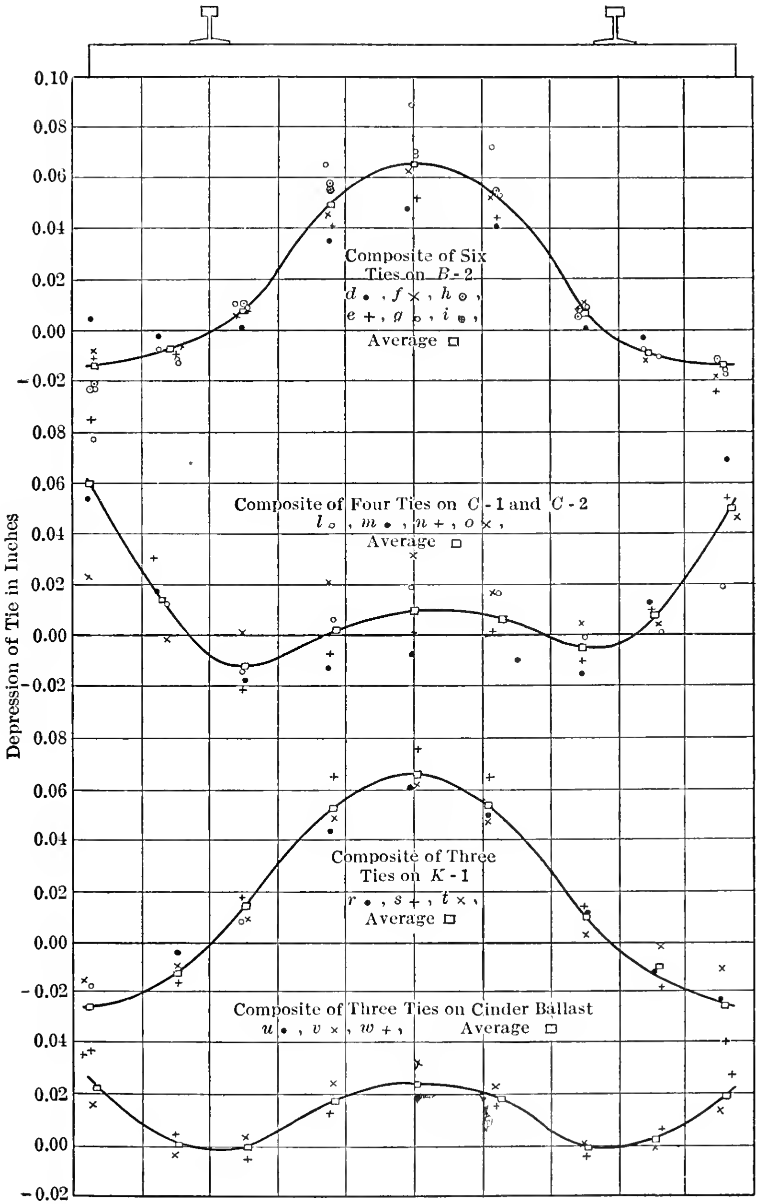


FIG. 55.—COMPOSITE DIAGRAMS OF TIE FLEXURE, ILLINOIS CENTRAL RAILROAD.

ends of the tie. Change in position of the ballast under traffic conditions will soon modify the distribution of bearing pressure. Even though the tamping is restricted to a space adjacent to the two rails, the depression of the track under load may be expected to bring some bearing pressure at the middle of the tie length, and the action of a repetition of applications of pressures of high intensity over the tamped portion will cause a movement of the ballast and a redistribution of bearing pressures.

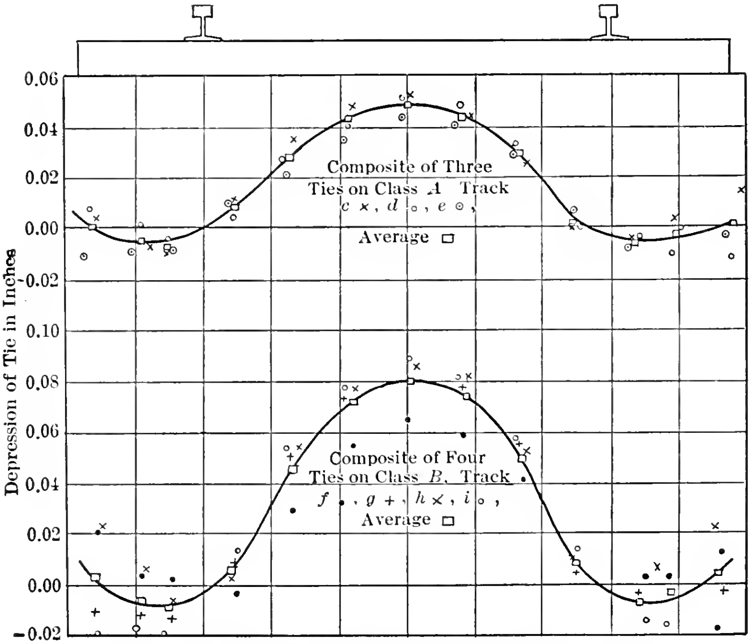


FIG. 56.—COMPOSITE DIAGRAMS OF TIE FLEXURE, CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY.

The condition of the ballast section at and beyond the end of the tie seems to have a modifying influence upon bearing conditions. The scantness of the shoulder in Section *B* of the Illinois Central Railroad evidently contributed to the loose ends and play of many of these ties, especially those whose looseness was noticeable by inspection; the effect of this probably becoming apparent only after traffic had produced appreciable changes in the position of the particles of ballast. The more complete support at end of tie in the ballast section on the Chicago, Milwaukee and St. Paul Railway gives conditions which are quite different.

The initial position of the ballast bed with respect to the bottom of the tie for the compact condition of ballast existing in the track tested

TABLE 15.—TESTS OF DEPRESSION AND FLEXURE OF TIES.

Location.	Number tested.	Designation.	Ballast.	Remarks.
		ILLINOIS CENTRAL RAILROAD		
A	2	*A a, b*	12-in. stone	85-lb. rail; 7 by 9-in. by 8-ft. oak ties.
B	1	*B*-1 *c*	do	6 by 8-in. by 8-ft. oak ties.
	6	*B*-2 *d, e, f, g, h, i.*	do.	do.
B (joint)	2	*B* (joint) *j, k*	do.	do.
C	1	*C*-1 *l*	6 in stone	do.
	5	*C*-2 *m, n, o, p, q*	do.	do.
K	3	*K r, s, t*	24-in. stone	125-lb. rail; 6 by 8-in. by 8-ft. oak ties.
North-bound freight lead.	3	Cinder, *u, v, w*	12-in. cinder.	85-lb. rail; hewn ties.
		CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY		
Class A track	5	Class A *a, b, c, d, e*	36-in. gravel.	100-lb. rail; 7 by 8 in. by 8-ft. 6-in. oak ties.
Class B track	4	Class B *f, g, h, i*	do.	75-lb. rail; 6 by 8-in. by 8-ft. soft wood ties.

may be found approximately by the following method. In any diagram of depression and flexure (as, for example, Fig. 47), for each point along the tie and each depressed position lay off a horizontal distance proportional to the load producing the given tie depression. The points so measured for the three loads used will be found to lie almost in a straight line. Produce such a straight line to intersect the vertical line through the initial position of the point on the tie. This intersection would be the initial position of the ballast bed under the point on the tie if the bearing pressure was uniform along the tie. A second approximation (which it is not generally necessary to make) may be made by assuming that at any given point the intensity of the bearing pressure accompanying each load varies as the vertical distance from the point just found to the position occupied at the given load. This method will locate quite closely the initial position of the bed for track with well compacted ballast. The bending of the tie to fit minor depressions, such as that which may exist directly under the rail, is not taken into account; this would modify the results but slightly. The dotted lines given in the figures, obtained in the manner described, may then be expected to represent fairly closely the initial position of the bed under the tie. Play is given by the space between this line and the tie. It will be seen from the diagrams that the ties which show large upward curvature at the middle have their beds curved in

the same manner; in other cases the bed at the middle is much lower than at the ends of the tie—the play between tie and bed being at the ends in one case and at the middle in the other.

As the amount of depression affects the modulus of elasticity of rail-support, *u,* it may be expected that the condition of tie and ballast will be influential factors. In determining *u,* the play in track depression was omitted from the values, though of course it enters into the development of stresses in the rail and is known to produce higher stresses than would otherwise occur, especially if the play varies from tie to tie. The bending of the ties, however, and especially that under the rail, tends to make low values of *u.* Another element contributing toward the higher value of *u* in the Chicago, Milwaukee and St. Paul Railway track, already referred to, seems to be the gravel ballast; there are fewer voids and a greater cross-section of material to take the load and therefore the amount of compression in the ballast may be expected to be less. The modulus of elasticity of the limestone used on the Illinois Central Railroad is less than that of the gravel of the Chicago, Milwaukee and St. Paul Railway.

Attention is called to the fact that the deflections in the flexure curve of the 7 by 9-in. ties are much smaller than those in the 6 by 8-in. ties; for the same loading the deflections may be expected to vary inversely as the moment of inertia of the section and the moment of inertia of the 7 by 9-in. tie is nearly 70% greater than that of the 6 by 8-in. tie. It may be added that the greater stiffness of tie should help in making more uniform pressures along the length of the tie.

The joint ties, *j* and *k* (see Figs. 36 and 48) were chosen for test because they were particularly loose and showed much play. The effect of tamping on this tie is very noticeable. The condition of the joint Tie *i* (see Fig. 48) is not especially different from the other ties in the vicinity.

The composite diagram for the ties on cinder ballast gives a good appearance, symmetrical and with apparent good end bearing, but it should be noted that these curves are not plotted from gross depressions; the individual ties give markedly different curves, tilting first to one side of the track and then to the other. This is due not only to the ballast and condition of tamping, but to the fact that the ties were unevenly spaced and did not always lie at right angles to the rails. The change from the greatest depression occurring at the end of a tie at one side of the track to the greatest depression at the other side of the track within a short distance was not confined to the freight tracks and cinder ballast. The tilting of the tie to one side of the track, however, was more common where the shoulder of ballast was scant.

The effect of the greater length of tie in Class A track will be considered in the next article.

26.—Bearing Pressure and Bending Moment.—If the intensity of the tie reaction were directly proportional to the measured tie depression it would be easy to find the distribution of the tie reaction along the length of the tie by the use of the diagrams of tie depressions already given. Two variations from this law of distribution of pressure are known to exist; (*a*), due to the condition of ballast bed under the tie the unloaded tie may not touch its bed at all points and (*b*), the ballast may be more compact and more stiff at one point than at another. Most of the uncertainty due to the first condition may be overcome by the use of the dotted line in the diagrams of tie depression as expressing the initial position of the tie bed; there may be a further depression in the bed due to the bending of the tie immediately under the rail, as shown in Fig. 54 (left end of Tie *h*). The dotted lines of the figures generally indicate a centerbound condition; this gives a bending moment at the middle of the tie when it is brought to a full bearing and increases the bending moment at all loads and also results in an increase of intensity of bearing pressure at the middle. A permanently formed depression at the rail acts to relieve the intensity of tie reaction there but increases the bending moment at this point when a load is applied which brings the tie down to full bearing. The second condition, that not giving direct proportionality between depression and intensity of bearing pressure, is particularly evident in freshly placed ballast. In well compacted ballast the variation from proportionality may be expected to be slight. Immediately after tamping, the bed may be somewhat stiffer at the point of tamping; as the effect of tamping disappears through the movement of the particles of ballast, the yieldability of the ballast under load, that is, the modulus of elasticity of the mass, tends to become more uniform along the length of the tie. By taking into consideration the effect of variations in these conditions the diagrams of tie depression and flexure will be found useful in indicating the range of variation of bearing pressure and bending moment.

It will be of interest to consider a variety of assumed distributions of bearing pressure (tie reactions) and the resulting distribution of bending moments. Fig. 57 gives a number of hypothetical cases. Uniform pressure shown at (*a*) cannot be expected. For a few inches at the end of the tie the bearing pressure must be small. The flexure of the tie itself will also produce a variation from uniformity of pressure. At (*b*) is shown a diagram indicating the influence of these factors when the initial bearing is fair and the stiffness of the bed is uniform along the length of the tie. At (*c*) is the distribution sometimes thought to exist when the tie is tamped for a foot or so on each side of the rail. Diagram (*d*) gives the distribution for freshly tamped sand ballast as found by laboratory measurements with pressure capsules—little pressure was here found at the middle of the tie; (*e*) assumes the

principal bearing to be at the rails tapering off in each direction; (*f*) assumes maximum intensity at the end of the tie and (*g*) at the middle; (*h*) represents a form of distribution for the centerbound tie, somewhat as was found for the medium load in some of the tests; (*i*) represents the distribution for an endbound tie; (*j*) may be considered as representative of the pressures under a well tamped tie in compact ballast after traffic has begun to have an effect. It is possible that at the point of greatest depression, as immediately under the rail, a permanent depression will be formed and the tie will not touch the bed until it has bent considerably at this point. This condition tends to give a decreased intensity under the rail, as shown at (*k*), but the effect of this on the distribution is not large.

TABLE 16.—BENDING MOMENTS IN TIE FOR ASSUMED DISTRIBUTIONS OF BEARING PRESSURE.

W = Total load, in pounds, carried by one tie. Moment is then given in pound-inches.

Distribution as designated in Figure.	8-FT. TIE.		8-FT. 6-IN. TIE.		9-FT. TIE.	
	At rail.	At middle.	At rail.	At middle.	At rail.	At middle.
a	+ 1.5 W	− 2.7 W	+ 1.9 W	− 2.0 W	+ 2.5 W	− 1.2 W
b	+ 1.6 W	− 1.7 W	+ 2.1 W	− 1.0 W	+ 2.5 W	− 0.5 W
c	+ 1.8 W	0.0 W	+ 1.8 W	0.0 W	+ 1.8 W	0.0 W
d	+ 1.3 W	− 1.5 W	+ 1.8 W	− 0.9 W	+ 2.1 W	− 0.5 W
e	+ 0.9 W	− 1.8 W	+ 1.2 W	− 1.3 W	+ 1.5 W	− 0.8 W
f	+ 2.8 W	+ 1.2 W	+ 3.6 W	+ 2.2 W	+ 4.4 W	+ 3.2 W
g	+ 0.1 W	− 6.7 W	+ 0.3 W	− 6.2 W	+ 0.5 W	− 5.7 W
h	+ 1.3 W	− 3.9 W	+ 1.6 W	− 3.3 W	+ 2.0 W	− 2.6 W
i	+ 2.0 W	− 0.4 W	+ 2.7 W	+ 0.6 W	+ 3.3 W	+ 1.4 W
j	+ 1.4 W	− 2.4 W	+ 1.9 W	− 1.8 W	+ 2.4 W	− 1.0 W
k	+ 1.6 W	− 1.9 W	+ 2.1 W	− 1.1 W	+ 2.6 W	− 0.4 W
l	+ 4.9 W	+ 5.2 W	+ 5.7 W	+ 6.0 W	+ 6.4 W	+ 6.7 W
m	+ 2.4 W	+ 0.6 W	+ 2.1 W	+ 1.4 W	+ 3.6 W	+ 2.2 W

The relative magnitudes of the bending moments at points along the tie is shown for these cases by the diagrams at the right in Fig. 57. Table 16 gives, for the distributions of bearing pressure assumed in Fig. 57, the values of the bending moment at two sections of the tie and for three lengths of tie. W is the total load on the tie in pounds and the moment is expressed in pound-inches. It is seen that there is a considerable range of values of the moments, both at the middle of the tie and at the rail. It is also to be noted that a slight change in the distribution of the intensity of bearing pressure along the tie makes a relatively large change in the amount and distribution of the bending moments.

A study of the flexure curves of the ties tested in track and a comparison with flexure curves corresponding to the distribution of moments given in Fig. 57 show that a variety of conditions of tie

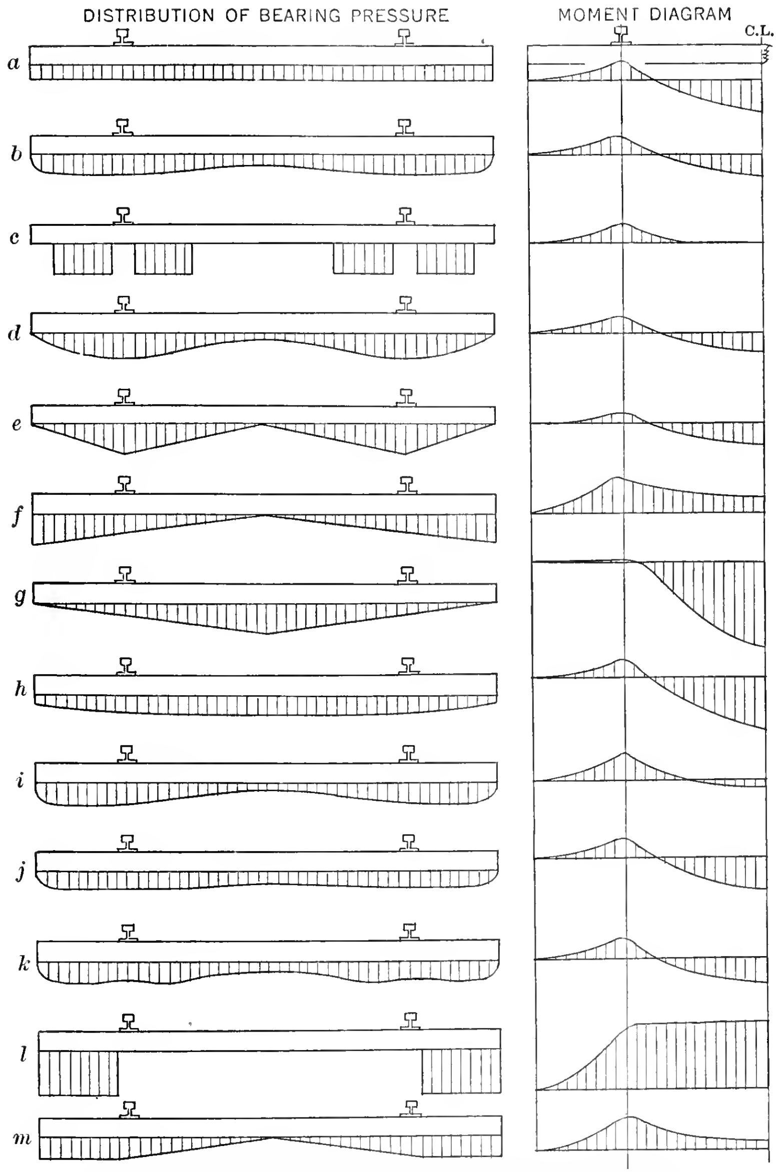


FIG. 57.—HYPOTHETICAL DISTRIBUTIONS OF BEARING PRESSURE AND CORRESPONDING MOMENT DIAGRAMS FOR TIE 8 FT. LONG.

bearing may exist. Even in well-tamped track the uniform distribution of bearing pressure indicated at (*a*) cannot occur. The intensity of bearing pressure will be greater near the rail than at the middle or end of the tie since the bending of the tie will result in larger depressions at that point. The more flexible the tie, the greater the variation in intensity; likewise, the stiffer the ballast, the greater the variation—all resulting in increased intensity of bearing pressure at the rail. Such a condition gives a smaller value of the bending moment at the middle of the tie than would be found for uniform bearing pressure. If the ballast at the middle of the track is less compact than elsewhere the difference becomes more pronounced. The bending moment at the rail for this condition is less than for the endbound condition. The condition given at (*c*) in Fig. 57 may be expected to merge into that at (*d*). With a concentration of pressures near the rails it may be expected that a permanent depression will soon be formed under the rail, a greater depression all along the tie will then occur upon the application of the heavy loads, and the bearing pressures will be distributed more uniformly along the tie. A permanently formed depression under the rail will increase the bending moment in the tie at the section under the rail.

In centerbound track, for the smaller loads, the tie reactions are carried mostly in a short space at the middle of the tie. These small loads act to bend the tie downward at its middle to fit the shape of the bed (as given for Tie *i* by the dotted line in Fig. 48); only a small load is needed to give this bending, particularly as the bed at the middle of the tie will be depressed under the action of the bearing pressure. Under the conditions of the tests with centerbound track, the load required to bring the tie to a bearing under the rail was probably not greater than 10% of the 100 000-lb. load used. The negative moment produced by this small load is, of course, relatively large. The loads used in the test give full bearing along the tie, the depressions from the original position of the bed (dotted line in the figure) not differing greatly from what would be found in well-tamped track.

For an endbound tie (see Tie *q* in Fig. 50), the bending moments developed with the small loads are all positive (curvature all downward), and for unusual conditions they may remain positive at the higher loads, as is instanced in Tie *o* after tamping (see Fig. 50). A more usual condition for what is commonly included as an endbound condition develops positive moments at the middle of the tie for the smaller loads and negative moments for the larger loads.

The curves of flexure of the ties (see Figs. 45 to 52) give information on the distribution of bending moments. Since the curvature of the curve of flexure of the tie varies as the bending moment developed, the distribution of bending moment along the tie may be determined if the curvature at various points is known.

If R is the radius of curvature of the curve of flexure at a given point, in accordance with beam theory the expression for the curvature at that point is $\frac{1}{R}$ and the bending moment M will be $\frac{E\,I}{R}$, where E is the modulus of elasticity of the wood and I is the moment of inertia of the cross-section of the tie. It had been expected that the data of tie flexure would be of such nature as to give fairly accurate means of determining the moments developed in the ties and their distribution. It has been found that the local vertical compression of the wood at and near the rail, due to the bearing pressure of the rail, affects the depressions of the points near the rail (the amount was small, but the flexure of the tie was also small) to such an extent as to modify the form of the curve of flexure and thus throw some uncertainty on the radii of curvature derived therefrom, even at the middle of the tie. The values found for sections at the middle of the tie are fairly accurate; those at the rail are somewhat less reliable. The average of the values found will be useful for comparison. It seems probable that measurements made at the middle of the edges of the tie would give data of more value.

The curves of flexure of the various ties, obtained from the measurements, have been studied; the results give at least a qualitative distribution of the moments. To determine the modulus of elasticity of the wood, ten of the ties tested in the track were tested in the laboratory. The ties were considered to have a moisture condition similar to that existing when they were in the track. The tie was supported as a beam of 90-in. span, two equal loads applied at points 25 in. from the center, and the center deflection read over a chord of 40 in. The resulting values of the modulus of elasticity, calculated by the formula for deflection of beams, ranged from 1 000 000 to 1 400 000 lb. per sq. in., for the oak ties, averaging 1 250 000 lb. per sq. in. For the soft wood tie from Class B track, the value was 800 000 lb. per sq. in.

Table 17 gives values of bending moments in the tie at its center and at the rail, determined from the flexure curves by the method above described for the data of the ties tested in the track. The moments are expressed in pound-inches, W being the load carried by the tie, in pounds. As has been stated, it is to be expected that the method used is subject to error, and some of the values of the bending moment at the rail seem very high. The data are useful, however, in giving quantitative values which may be developed in track service.

It will be seen that negative bending moments as much as — 4.5 W lb.-in. were developed at the center of the tie, W being the load carried by one tie. For well tamped track and track kept in good condition, the negative moment will be considerably smaller, and for such conditions a value as low as — 2.0 W may be expected as the upper limit. Excessive bearing pressures at the ends of the tie and needed strength

TABLE 17.—VALUES OF BENDING MOMENTS IN TIE DETERMINED FROM CURVES OF FLEXURE.

W = Total load, in pounds, carried by one tie. Moment is then given in pound-inches.

Location.	Bending moment at center of tie.	Bending moment at rail.
ILLINOIS CENTRAL RAILROAD		
Location *B*.		
Maximum value	− 3.7 W	+ 4.0 W
Minimum value	− 1.7 W	+ 1.4 W
Average value before tamping	− 2.5 W	+ 1.9 W
Average value after slight tamping	− 1.9 W	+ 3.2 W
Joint ties, Location *B*, average value	− 2.0 W	+ 1.4 W
Location *C*.		
Maximum value	− 4.1 W	+ 4.8 W
Minimum value	− 0.3 W	+ 1.7 W
Average value before tamping	− 1.4 W	+ 2.9 W
Average value after slight tamping	− 1.1 W	+ 3.4 W
Location *A*, average value	− 2.5 W	+ 2.0 W
Location *K*.		
Maximum value	− 2.5 W	+ 1.6 W
Minimum value	− 2.3 W	+ 1.0 W
Average value	− 2.4 W	+ 1.2 W
CHICAGO, MILWAUKEE AND ST. PAUL RAILROAD		
Class A track.		
Maximum value	− 4.5 W	+ 6.0 W
Minimum value	− 0.8 W	+ 3.2 W
Average value	− 2.5 W	+ 5.0 W
Class B track		
Maximum value	− 2.1 W	+ 3.7 W
Minimum value	− 0.9 W	+ 2.3 W
Average value	− 1.5 W	+ 3.3 W

in handling it make it seem desirable to provide also for a positive bending moment of + 1.0 W at the center.

For uniform bearing along the tie, the value of the bending moment at the rail would be about + 2.0 W lb.-in. for ties 8 ft. 6 in. long. In Table 17 values as high as + 4.8 W and + 6.0 W are found. It would appear that bending moments even larger than these values may be expected in track considered to be in ordinarily good condition. For first-class track in excellent condition it seems probable that a bending moment + 2.5 W at the rail should not be exceeded. The high values of bending moment at the rail obtained from the flexure curves are not readily explained; it seems probable that the depression of the fibers of the wooden tie under and near the rail, as indicated in Fig. 58, results in a greater flexure of the tie than would otherwise occur. Even though the bending moment found by the process used is, by reason of this condition under the rail, greater than that which exists by virtue of the bearing pressures between the rail and the end of the tie, the reduction in resistance to flexure produced by excessive depression of the fibers under the rail may be as much or more than the

discrepancy in bending moment, and hence values of the bending moment such as those given above are not too large for use under the conditions found with wooden ties.

The bearing pressure under the tie of course will vary in intensity along its length. A study of the data of the tie flexure tests indicates that the maximum bearing pressure per unit of length of tie, under static loading, will not ordinarily exceed twice the average bearing pressure over the length of the tie, and that for track in good condition the maximum will be less than one and one-half times the average. These values relate to bearing pressures per unit of length of tie; as will be shown in the next chapter of the report the variation in intensity of pressure from the edge to the middle point of the width of the tie is considerable and the maximum intensity at the middle of the width may be much greater than the average.

It may be noted that the heaviest load on a tie generally occurs under the closely spaced drivers of a heavy freight locomotive, and the static load on one tie may be found approximately by dividing the weight on a driving axle by the number of ties which come within a driver spacing.

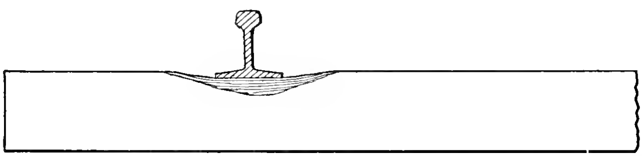


Fig. 58.—Diagram Showing Local Depression of Fibers Under Rail.

It should be noted that the present discussion relates to static loading—no allowance has been made for the effect of speed, counterweight, and impact in increasing the loads on the tie; these should be considered in finding the bending moments, stresses and bearing pressures which may develop in track service.

V.—Transmission of Pressures in Ballast.

A.—Analytical Discussion.

27.—Introductory.—Crushed rock, gravel, cinders, burnt clay, slag, and sand are the materials commonly used for ballast. These materials are practically devoid of cohesion, at least when first placed. Earth and clay possess cohesive properties in some degree. Non-cohesive materials consist of separate pieces which will be hereafter referred to as grains. The grains are of irregular size and shape, and when first placed form a loose mass which cannot carry load without considerable readjustments of their relative positions. Under repeated applications of load, or other working, the grains are rearranged so that the mass becomes quite compact.

By reason of its structure, a load is transmitted through a non-cohesive granular mass from grain to grain by contact pressures. The

distribution of pressure is made through chains of grains in contact which lie between the load and a point in the ballast. Consideration will be given first to special forms of grains and then to the general form found in ballast.

28.—The Transmission of Load Through a Pile of Cylinders.— Assume that the cylinders are piled as compactly as possible. There are three cases to consider: First, when the cylinders are frictionless; second, when the coefficient of friction is equal to or greater than tan. 30°; third, when the coefficient of friction is between these two conditions.

In the first case, since there is no friction between the cylinders, the pressure at the point of contact must be normal to the surfaces in contact; that is, the line of action of the pressure must pass through the centers of the cylinders in contact. All of the pressure therefore is transmitted through two chains, as shown in Fig. 59. It is evident that without adequate lateral support, the column of cylinders carrying the load will buckle, resulting in a rearrangement of the whole mass. The load-carrying capacity of a pile of frictionless cylinders is very small, because the only lateral forces which can be exerted are those due to the weights of the cylinders.

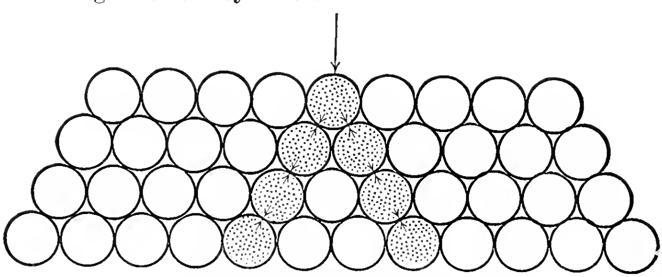


FIG. 59.—TRANSMISSION OF PRESSURES THROUGH PILE OF FRICTIONLESS CYLINDERS.

In the second case, when the coefficient of friction is equal to or greater than tan. 30°, all of the load applied to the upper cylinder can be carried by the two cylinders below without the aid of lateral pressure. These in turn can be supported by one cylinder below them, as shown in Fig. 60 at (*a*). In this case there are no lateral forces developed or required for stability. That equilibrium will exist under this condition may be seen from the diagram at (*b*). The vertical force $\frac{1}{2}P$ may be resolved into two rectangular components. The ratio of the tangential to the normal component is

$$\frac{\frac{1}{2}P \sin. 30^\circ}{\frac{1}{2}P \cos. 30^\circ} = \tan. 30^\circ$$

For values of the coefficient of friction less than tan. 30°, slipping will occur; for equal or greater values, equilibrium will exist.

In the third case, when the coefficient of friction is greater than zero and less than tan. 30° the distribution of load will be between the extreme conditions represented by the cases previously considered. The actual distribution will depend upon the value of the coefficient of

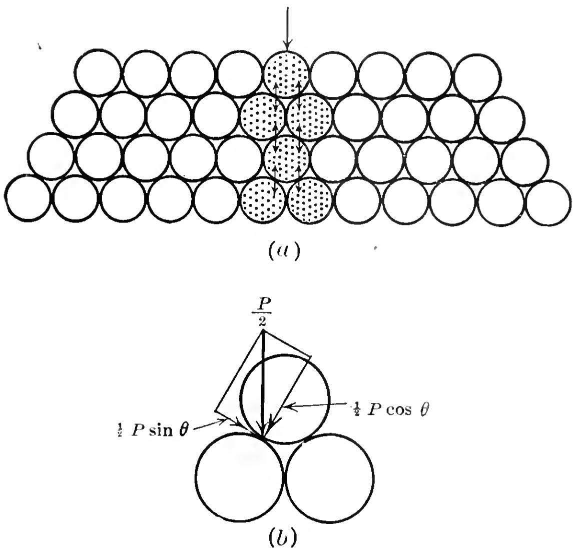


Fig. 60.—Transmission of Pressure Through Pile of Cylinders When Coefficient of Friction is Equal to or Greater Than Tan. 30°.

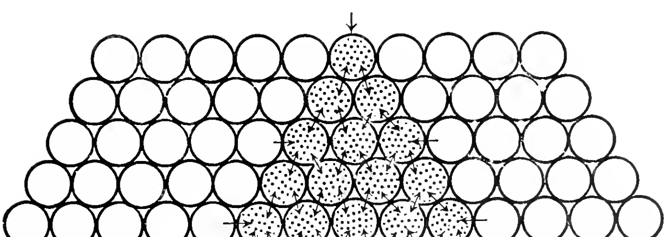


Fig. 61.—Transmission of Pressure Through Pile of Cylinders When Coefficient of Friction is 0.2.

friction. As an illustration, the distribution of pressures in direction and magnitude when the coefficient of friction is 0.2 is indicated in Fig. 61. It will be noted that in this case lateral pressures are required in alternate rows in order to keep the mass in equilibrium.

It has been shown, then, that even when considering the distribution of pressure through a pile of equal-sized, incompressible cylinders, arranged symmetrically, the problem becomes so complex that it would be difficult to obtain results of general value. The complication is

caused by the effects of the lateral components of the pressures between the grains. This suggests that grains be assumed of such shape that there will be no lateral forces.

29.—The Transmission of Pressures Through a Pile of Grains in Which There are no Lateral Pressures.—To make the problem as simple as possible it will be assumed that the grains are of such shape that each grain rests on two grains and that the points of contact are always on the vertical center lines of the grains below, the distribution of the pressure being lateral and not longitudinal. Such a pile is shown in Fig. 62. One-half of the load applied to any grain is

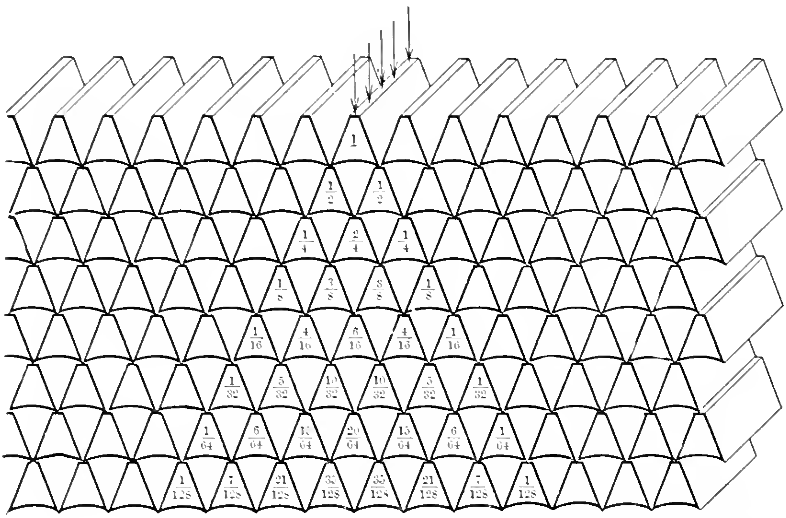


FIG. 62.—TRANSMISSION OF PRESSURE THROUGH PILE OF GRAINS WHEN NO LATERAL FORCES ARE DEVELOPED.

transmitted to each of the two grains below. In the first row below the loaded grain the pressure will be $\frac{1}{2}$ and $\frac{1}{2}$ of the applied load. In the second row below the loaded grain the pressures will be $\frac{1}{4}$, $\frac{2}{4}$, and $\frac{1}{4}$. In the third row it will be $\frac{1}{8}$, $\frac{3}{8}$, $\frac{3}{8}$, and $\frac{1}{8}$. In the nth row it will be:

$$\left(\frac{1}{2}\right)^n, n\left(\frac{1}{2}\right)^n, \frac{n(n-1)}{1 \times 2}\left(\frac{1}{2}\right)^n, \frac{n(n-1)(n-2)}{1 \times 2 \times 3}\left(\frac{1}{2}\right)^n, \text{ etc.}$$

That is, in any row, the pressures on the grains will be represented by the terms found by the expansion of the binomial

$$\left(\frac{1}{2}+\frac{1}{2}\right)^n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

For example, in the bottom row of Fig. 62,

$$\left(\frac{1}{2}+\frac{1}{2}\right)^7 = \left(\frac{1}{2}\right)^7 + 7\left(\frac{1}{2}\right)^7 + \frac{7 \times 6}{1 \times 2}\left(\frac{1}{2}\right)^7 + \text{etc.}$$

It can be shown that the distribution of pressure given by this equation when n is large is similar to that given by the curve known as the probability curve. The equation giving this distribution of pressure on any horizontal plane is

$$p = \frac{k\, p_0}{\sqrt{\pi}}\, e^{-k^2 x^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

in which p is the pressure at a horizontal distance x from the center line of the applied load, e is the Naperian base of logarithms, p_0 is the applied pressure and k is a function of the distance below the loaded grain. The form of the curves given by the equation may be judged from the three curves in Fig. 65.

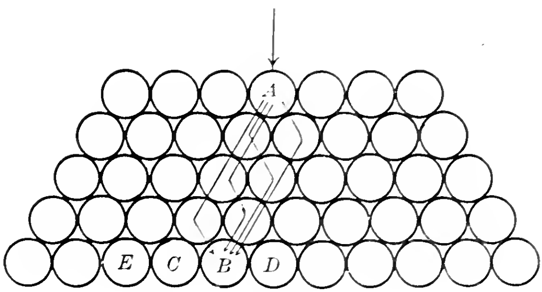


FIG. 63.—PATHS OF PRESSURE IN PILE OF CYLINDERS.

It is apparent that the condition assumed, each grain of ballast resting on the vertical center lines of two others, is a very special case. Results quite similar to those obtained above are found when the grains are of such form and arrangement that each grain rests on the vertical center line of three grains or of four grains. While the results found on such assumptions may not be quantitatively applicable, the analysis is of aid in forming a conception of the manner in which pressure is distributed and in giving a basis for expressing the results of experiments with ballast.

30.—Paths of Pressure and Law of Distribution of Pressure.—In general there are a number of paths which the pressure may take as it is transmitted from one grain to another in the ballast; that is, there are a number of chains of grains in contact between the two grains under consideration. In Fig. 63 all of the possible paths of pressure between a loaded grain A and a grain B are indicated by lines. In this particular case there are four paths. Between Grains A and C there is only one path. Between A and E there is no path. Between A and D it can be shown that there are six paths. Referring also to Fig. 62 it will be seen that the number of chains of grains between A and B, C or D is the same as the numerator of the fractions representing

the pressures on the corresponding grains in the fourth row below the loaded grain.

In the preceding discussion, only grains of uniform size, special shape, and symmetrical arrangement have been considered. In ballast the grains have an infinite variety of sizes and shapes and are irregularly piled. Even with such irregular material the only method by which pressure can be transmitted from one grain to another not in contact with it is by means of chains of grains in contact with one another in the intervening space. Because of the irregular sizes, shapes and arrangements of the grains it is not possible to deduce a mathematical expression giving the amount of pressure transmitted from one grain to another in a particular case, but it has been found that by means of experiments and the use of the laws of averages good pre-

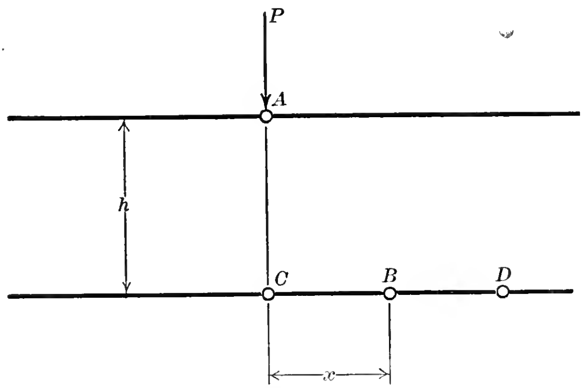


FIG. 64.—DIAGRAM SHOWING RELATIVE POSITIONS OF LOADED GRAIN AND POINTS ON HORIZONTAL PLANE.

dictions may be made. The following discussion of the probable distribution of pressure from a loaded grain has been found to accord with experimental results.

Assume a load P applied to a grain A at a height h above a horizontal plane on which there is a grain B, as shown in Fig. 64. Between A and B there are various paths of pressure, or chains of grains, through which pressure is transmitted. The number of paths, or chains, will in general increase as B is taken nearer to C (the grain directly under A) and will in general diminish as the distance x from C is increased until a point D is reached beyond which there is no chain of grains transmitting vertical pressure. Between A and C the number of paths is a maximum for that depth. In view of the discussion in the preceding articles, it seems reasonable to assume that the pressure transmitted to any grain will in general be proportional to the number of chains of grains between the two grains, and it may also be expected that in general the number of chains of grains from A to any grain B on the

given plane at any distance x from the center, and hence the pressure transmitted, will vary in accordance with the law of distribution of pressure represented by Equation (14) on page 123. This law of the distribution of pressure is confirmed by the experiments.

This equation, then, may be taken to express in a general way the probable form of the distribution curve of the vertical pressure transmitted from a loaded grain in ballast consisting of grains of irregular size and shape and placed in any manner. It should be noted that the transmission is considered to take place only laterally, that is, in a vertical plane, it being virtually assumed that other similar transmission exists in adjacent parallel vertical planes, as would be the case with a cross-tie and ballast. In the case of tie and ballast, due to variation in bearing pressure along the length of the tie, there will be some longitudinal transmission of pressure, tending toward greater uniformity of pressure parallel to its length, but this action may be considered separately. For a load applied to a single grain, instead of to grains along a line, the transmission horizontally would be in every direction and the distribution would give equal intensities along the circumference of horizontal circles, making an entirely different distribution from the case under consideration.

Since Equation (14) is an expression of the pressure on any grain in terms of the pressure on a single grain and does not give intensity of pressure, it is not in form for use. Assume the load to be applied to the ballast by means of a long narrow strip one unit wide. The pressure on any grain in the ballast will then be the sum of the pressures which would be found by use of Equation (14) applied to each grain in contact with the strip, and the resulting intensity of pressure at any point in the ballast may be expressed by an equation of the same form. Let p_a be the applied unit pressure, let h be the depth of ballast above a horizontal plane, and let x be the horizontal distance from the line of action of the applied load to the point on the horizontal plane at which it is desired to determine the intensity of pressure p, then

$$p = \frac{k\,p_a}{\sqrt{\pi}}\,e^{-k^2x^2} \quad \text{.......................(15)}$$

k being a factor which depends upon h and must be found by experiment.

31.—Lines of Pressure.—In Fig. 65 curves have been constructed to represent the distribution of vertical pressure on several horizontal planes *ABC, DEF,* and *GHI.* The total areas under the curves represent the total upward reactions in the ballast on the horizontal planes. The upward reactions must be equal to the applied unit-load p_a when a section of ballast 1 in. long is considered. The areas under the several curves are therefore equal. These areas have been divided into a number of equal parts, each representing the same fractional part of the

reaction. The location of the resultant for each fractional area is noted on Fig. 65. Lines drawn through these points may be considered as lines of pressure representing the resultant fractional pressures.

The lines of pressure thus drawn are analogous to lines of force in a magnetic field, and the intensity of vertical pressure at any depth is seen to be equal to the number of lines of pressure passing through a width of 1 in. multiplied by the pressure which each line represents. For instance, if the lines are drawn representing pressures of 3 lb. and

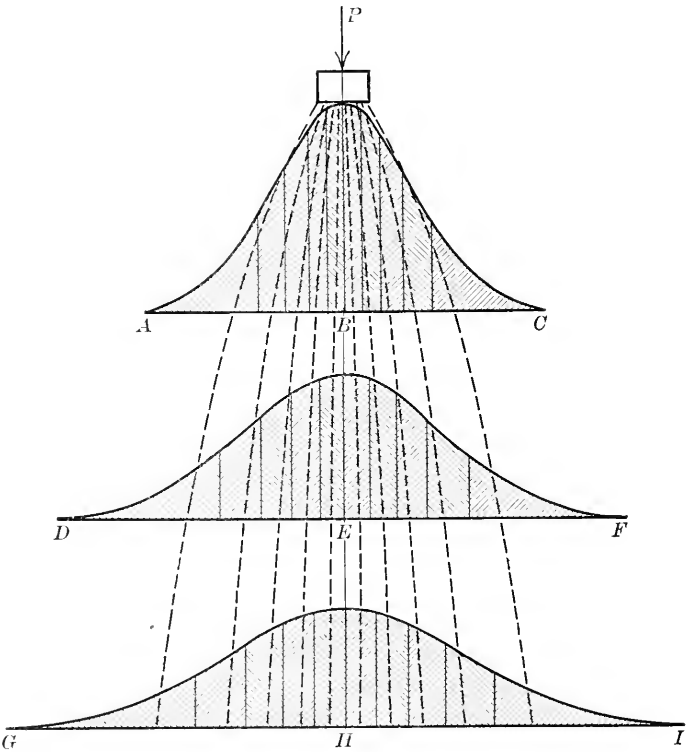


FIG. 65.—DIAGRAM ILLUSTRATING USE OF LINES OF PRESSURE.

at a given place on a horizontal plane four lines pass through a width of 1 in., the intensity of pressure is approximately $3 \times 4 = 12$ lb. per sq. in.

These lines of pressure will be found useful in explaining concentrations and distributions of pressure in ballast and in giving a conception of the manner of transmission of pressure.

32.—Rankine's Theory of the Relations of Pressures in a Granular Mass Devoid of Cohesion.—In 1856 Professor Rankine, from a study

of certain properties of stress relating to a infinitesimal wedge of granular material, enunciated several important theorems which have since borne his name. Several of these bear upon the discussion. They may be stated as follows:

Conjugate Stresses.*—*If any state of stress exists at a point in a granular mass, the stress acting on a plane through the point will be parallel to a second plane through the point, and the stress acting on the second plane will be parallel to the first plane. Stresses so related are called conjugate stresses.*

In Fig. 66, let the elementary prism be in equilibrium when acted upon by the stresses p parallel to AC, and the stresses q, direction unknown. It is required to find the direction of stresses q. Now the stresses p acting on the faces AB and CD must constitute a pair of forces in equilibrium; then to have equilibrium stresses q acting on the faces AC and BD must form a pair of forces in equilibrium, which can only occur when the stresses q are parallel to AB and CD.

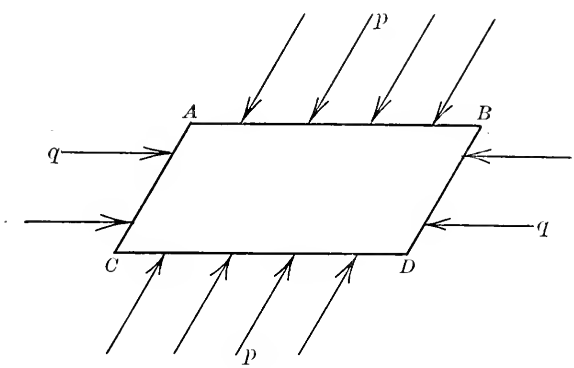


FIG. 66.—PARALLELOPIPED UNDER ACTION OF CONJUGATE PRESSURES.

Principal Stresses.*—*In any state of stress there is one pair of conjugate stresses at right angles to each other; i. e., there are two planes, at right angles to each other, on which the stress is normal only. Stresses so related are principal stresses.* For consider a plane at the point to rotate. There will be some position where the stress on the plane is normal; the plane at right angles will have a conjugate stress which is also normal. It can be shown that one of the principal stresses is the greatest stress and the other principal stress is the least stress at the point. Any possible state of stress can be completely defined by principal stresses.

* Taken with slight modifications from Ketchum's "Walls, Bins and Grain Elevators", to which the reader is referred.

The Ratio of Conjugate Pressures.—*The ratio of the intensity of the pressures on any pair of conjugate planes of pressure when motion is impending, is expressed by the equation:*

$$\frac{p_b}{p_a} = \frac{\cos.\theta - \sqrt{\cos.^2\theta - \cos.^2\phi}}{\cos.\theta + \sqrt{\cos.^2\theta - \cos.^2\phi}} \quad \ldots\ldots\ldots\ldots\ldots (16)$$

in which the stress p_a is greater than its conjugate unit stress p_b, θ is the common angle of obliquity which the stresses make with the normals to their planes, and ϕ is the angle of repose of the material.

When the angle θ is taken as zero, the conjugate stresses are perpendicular to their planes, hence p_a and p_b are the principal stresses. When motion is impending,

$$\frac{q}{p} = \frac{1 - \sin.\phi}{1 + \sin.\phi} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

in which p and q are the greatest and least principal stresses respectively.

Equations (16) and (17) express the relationships existing between conjugate pressures and principal pressures when motion is impending. The principal pressure q and the pressure p_b are *active pressures* developed by the application of their conjugate pressures. In case the resisting pressure is less than the active pressures the granular material will flow. In case the lateral pressures are greater than indicated by the equations, the granular mass will be in equilibrium.

33.—Conditions Accompanying the Application of Pressure by Means of a Tie.—In the preceding discussion it has been assumed that the pressure is applied only to a narrow strip. When the pressure is applied to the ballast by means of a tie the load is applied of course to the many grains in contact with the tie. It is common to consider that the intensity of pressure is the same all over the bottom of the tie and that it is normal to it (vertical). There is, however, a variation of the intensity of the pressure on the bottom of the tie due to the tendency of the ballast to move from the center to the edge of the tie when load is applied. Friction between tie and ballast develops pressures on the ballast which are not vertical. The maximum variation of pressure due to these causes will occur when the load is so great that the tie is being forced into the ballast. The following analysis will indicate the law of distribution under this condition of loading.

34.—Variation of Intensity of Pressure on the Bottom of the Tie When the Tie is Being Forced into the Ballast.—The friction between the tie and the ballast is probably less than the friction between the particles of the ballast, hence the ballast in contact with the bottom of the tie will be the first to move when the tie is heavily loaded. Consider a section of tie one unit long. Let the vertical unit-pressure at the edge be p_o, at the center be p_c, and at a distance x from the edge

be p. Let the coefficient of friction between the tie and the ballast be f, and the width of the tie be b. Let the total load on the tie be P and let l be the length of the tie. When motion is impending the intensity of pressure increases from the edge to the center of the tie because the intensity of vertical pressure at any point is limited by the available lateral pressure.

In Fig. 67 at (a), p_a is the resultant intensity of pressure at any point on the bottom of the tie when motion is impending. Expressed in terms of the vertical unit-pressure p at the point, the value of p_a is

$$p_a = \frac{p}{\cos.\ \theta}$$

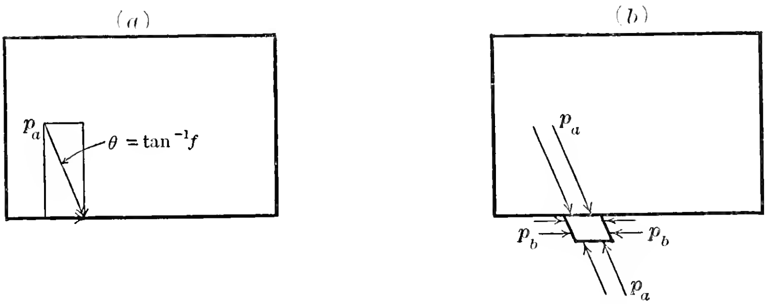


FIG. 67.—DIAGRAMS ILLUSTRATING PRESSURES ON BOTTOM OF TIE.

The horizontal pressure in the ballast at the point is the conjugate of the pressure p_a and may be found from Equation (16). For given values of θ and ϕ, using k as the resulting constant,

$$p_b = k p_a$$

in which

$$k = \frac{\cos.\ \theta - \sqrt{\cos.^2\ \theta - \cos.^2\ \phi}}{\cos.\ \theta + \sqrt{\cos.^2\ \theta - \cos.^2\ \phi}}$$

The total frictional force from the edge of the tie to a point x distant is equal to the horizontal thrust $\frac{k\,p}{\cos.\ \theta}$. In the distance dx, Fig. 68, the added friction amounts to $f\ p\ dx$, which can hold in equilibrium an additional horizontal thrust equal to

$$\frac{k\ dp}{\cos.\ \theta} = f\ p\ dx$$

Hence

$$\frac{k}{\cos.\theta}\int_{p_0}^{p}\frac{dp}{p} = f\int_0^x dx$$

Integrating,

$$\frac{k}{\cos.\theta}\log._e\frac{p}{p_0} = f\,x$$

$$\frac{p}{p_0} = e^{\frac{f\,x\cos.\theta}{k}} \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(18)$$

where e is the Naperian base of logarithms. The vertical unit-pressure at the center is

$$p_c = p_0\,e^{\frac{f\,b\cos.\theta}{2\,k}} \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(19)$$

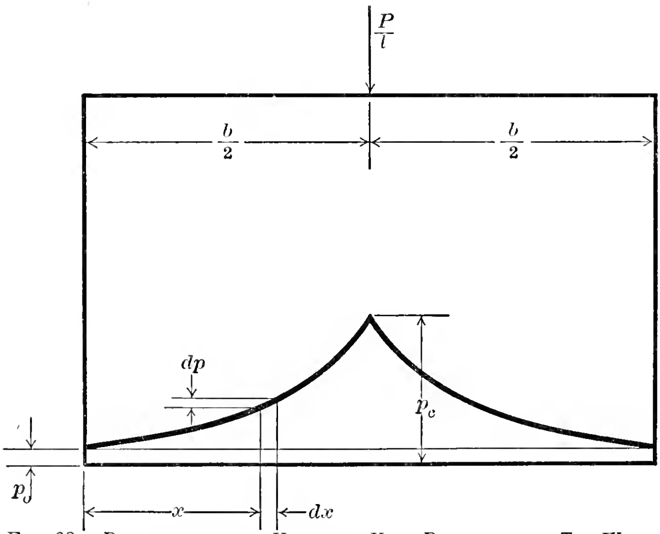


FIG. 68.—DISTRIBUTION OF VERTICAL UNIT-PRESSURE ON TIE WHEN CARRYING ULTIMATE LOAD.

The total load which can be carried by the section of the tie without its being forced into the ballast is equal to the area under the curve in Fig. 68.

$$\frac{P}{l} = \frac{2\,p_0\,k}{f\cos.\theta}\left(e^{\frac{f\,b\cos.\theta}{2\,k}} - 1\right)\ldots\ldots\ldots\ldots\ldots(20)$$

This equation gives the ultimate load, P, which the tie will support.

The average vertical unit-pressure carried by the tie is

$$\frac{1}{b}\cdot\frac{2\,p_0\,k}{f\cos.\theta}\left(e^{\frac{f\,b\cos.\theta}{2k}} - 1\right)\ldots\ldots\ldots\ldots\ldots(21)$$

The ratio of the vertical unit-pressure at the center to the average vertical unit-pressure on the tie is

$$\frac{p_c}{\frac{P}{b\,l}} = \frac{f\,b\cos.\theta\;e^{\frac{f\,b\cos.\theta}{2\,k}}}{2\,k\left(e^{\frac{f\,b\cos.\theta}{2\,k}} - 1\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots(22)$$

In making numerical calculations it is best to change from the Naperian base to the base of common logarithms by means of the equation

$$e^{\frac{f\,b\cos.\theta}{2\,k}} = (10)^{\frac{f\,b\cos.\theta}{4.6\,k}}.$$

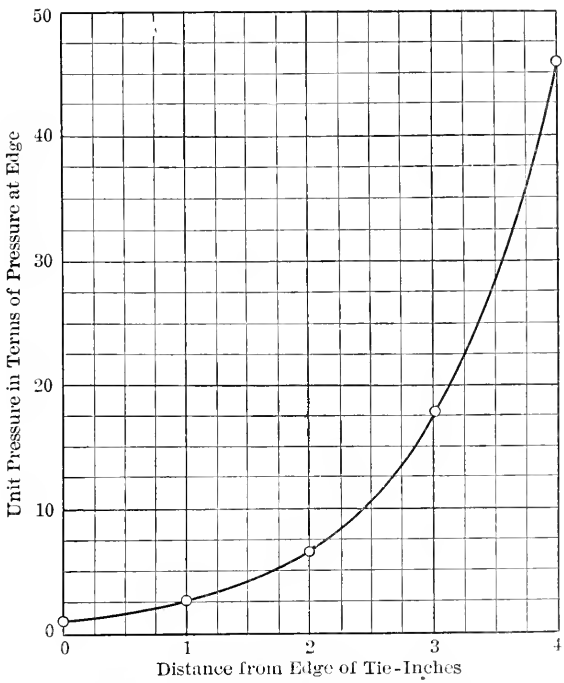


FIG. 69.—DIAGRAM SHOWING RELATIVE PRESSURES ON TIE WHEN CARRYING ULTIMATE LOAD FOR TAN. $\phi = 2/3$ AND TAN. $\theta = 0.4$

Values calculated from Equation (18) have been plotted in Fig. 69, which gives the greatest intensity of pressure that can exist at points away from the edge of the tie in terms of the intensity of pressure at the edge of the tie for assumed conditions of friction. It illustrates the rapid increase in intensity from the edge of the tie inward, which could be developed under the assumed conditions, when the tie is on the point of being forced into the ballast.

The ultimate supporting power of the tie is shown by Equation (20) to increase rapidly with the width. Using the assumptions here made, Table 18 gives the relative ultimate supporting capacity of ties of various widths, for tie on point of being forced into the ballast, based on an angle of repose of $1\frac{1}{2}$ to 1 and on a coefficient of friction between tie and ballast of 0.4. This is intended to represent approximately the conditions during quiescent loading. The relative ultimate supporting capacity of ties of various widths, for tie on point of being forced into the ballast, based on an angle of repose of 3 to 1 and on a coefficient of friction between tie and ballast of 0.2, is also given. This is thought to approximate the conditions when the application of load is accompanied by jarring as in the case of train loads. The exact values of the friction angles are not known. Table 18, of course, has an analytical, rather than an experimental basis.

TABLE 18.—Relative Supporting Capacities of Ties of Different Widths, for Quiescent Loadings and for Loadings Accompanied by Jarring, for Tie on Point of being Forced into the Ballast.

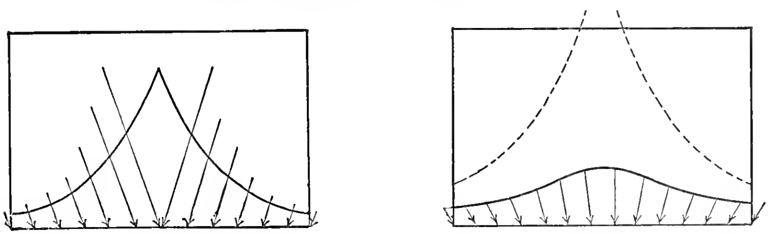
Quiescent load condition is based on assumed coefficient of 0.4 between tie and ballast and of $\frac{2}{3}$ between particles of the ballast. For jarring loads values of 0.2 and $\frac{1}{3}$ are assumed.

Width of tie, inches.	Ultimate Supporting Capacity.			
	In terms of p_0.		In terms of 8-in. tie.	
	Quiescent.	With jarring.	Quiescent.	With jarring.
1	1.27	1.08	0.01	0.07
2	3.33	2.34	0.04	0.15
3	6.65	3.79	0.07	0.24
4	12.1	5.55	0.13	0.35
5	20.7	7.55	0.22	0.47
6	34.8	10.0	0.37	0.62
7	57.4	12.7	0.61	0.80
8	93.7	16.0	1.00	1.00
9	153	19.1	1.63	1.20
10	248	24.2	2.65	1.51
11	401	29.5	4.27	1.85
12	650	35.2	8.94	2.20

Except when heavy loads are carried on loose ballast, the distribution of pressure on a railroad tie is not in general that shown in Fig. 69, because the tie is not at the point of being forced into the ballast. After the track has been in service for a time the ballast beneath the tie will become compacted. The carrying capacity of the ballast at the edge of the tie will then have been increased, and since the ultimate carrying capacity of the tie varies directly with the carrying capacity of the ballast at the edge of the tie, the ultimate carrying

capacity will also have been increased over what it could carry when the ballast was first placed.

At (*a*) in Fig. 70 is shown the distribution of pressure on the bottom of the tie when it is carrying its ultimate load. Vectors giving the directions and relative magnitudes of the unit-pressures are shown. The ordinates of the full line curve represent the vertical components of these pressures. When the tie is on the point of being forced into the ballast, the angle which the pressure makes with the normal to the bottom of the tie is the angle of friction between tie and ballast. The ultimate vertical unit-pressure which may be developed on the bottom of the tie after the ballast has become compacted is indicated by the dotted curve at (*b*) in Fig. 70. The distribution and direction of pressure on the tie under ordinary loadings (that is, loadings less than the ultimate load which the ballast can carry) will be somewhat as shown by the full line curve and the vectors. It is seen that the distribution shown is different from that at ultimate load.



(*a*) (*b*)

FIG. 70.—DIAGRAM SHOWING RELATIVE DIRECTIONS AND MAGNITUDES OF PRESSURES ON TIE UNDER ULTIMATE LOAD AND UNDER ORDINARY LOADS.

The coefficient of friction between the tie and ballast and between parts of the ballast will be much less under the jarring and pounding action of train loads than under loads applied without shock or vibration. The ballast gradually works from under the tie and in time the track must be retamped. From the discussion it is evident that in tamping it is not enough to force ballast beneath the tie unless the ballast at the edge of the tie is compacted, otherwise the track will settle rapidly. Especial attention therefore should be given to methods of tamping which insure a compacted ballast at the edge of the tie.

35.—Method for Finding the Distribution of Pressure in Ballast Beneath a Cross-Tie.—It has been shown that the pressure in ballast against the tie is greater near the center than at the edge of the tie and that because of the friction between tie and ballast the pressures are not perpendicular to the bottom of the tie. It has also been shown that the distribution of pressure in granular material when a narrow strip is loaded may be represented by an expression of the type of the probability equation, or by lines of pressure. By dividing the bottom surface

of the tie into narrow strips and using the average load on each strip and taking its direction into account, the total intensity of pressure at any point in the ballast may be found by adding the pressures at that point due to the loads on the several strips.

In order to use Equation (15) to find the vertical pressure at any point B in the ballast due to a pressure p_a at A, Fig. 71, when p_a is not vertical, it is necessary to determine the distances x_1 and h_1, and use them for x and h in Equation (15). It may be shown from the geometrical relations that

$$x_1 = (h \tan. \theta - a + x) \cos. \theta \dots\dots\dots\dots (23)$$

$$h_1 = \frac{h - x_1 \sin. \theta}{\cos. \theta} \dots\dots\dots\dots (24)$$

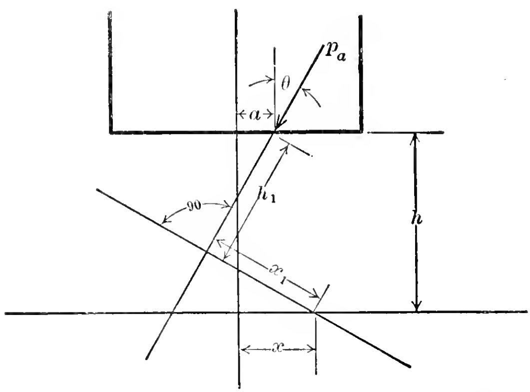


FIG. 71.—DIAGRAM FOR DETERMINING x_1 AND h_1.

The pressure p found from Equation (15) is in the direction of the pressure p_a. The vertical component of the pressure is found by multiplying the pressure found by cos. θ.

The pressure p_a at any point on the bottom of the tie probably should be taken as the greatest principal pressure at the point. The greatest principal pressure will make a greater angle with the vertical than does the conjugate pressure and its magnitude is greater. However, due to the uncertainties in the magnitude and direction of the pressures on a tie, it is a needless refinement to take account of the principal pressures, and values of the conjugate pressures will be used instead.

B.—Experimental Work in Laboratory.

36.—Earlier Experiments at the University of Illinois.—Experimental work on the transmission of vertical pressure through granular material was carried on for a number of years at the University of

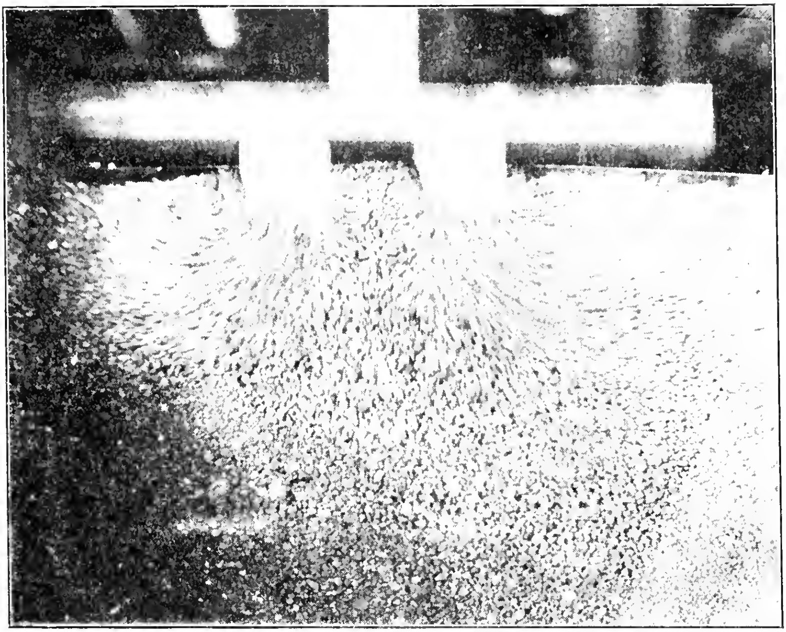


FIG. 72.—LINES OF MOVEMENT OF SAND BALLAST UNDER LOAD.

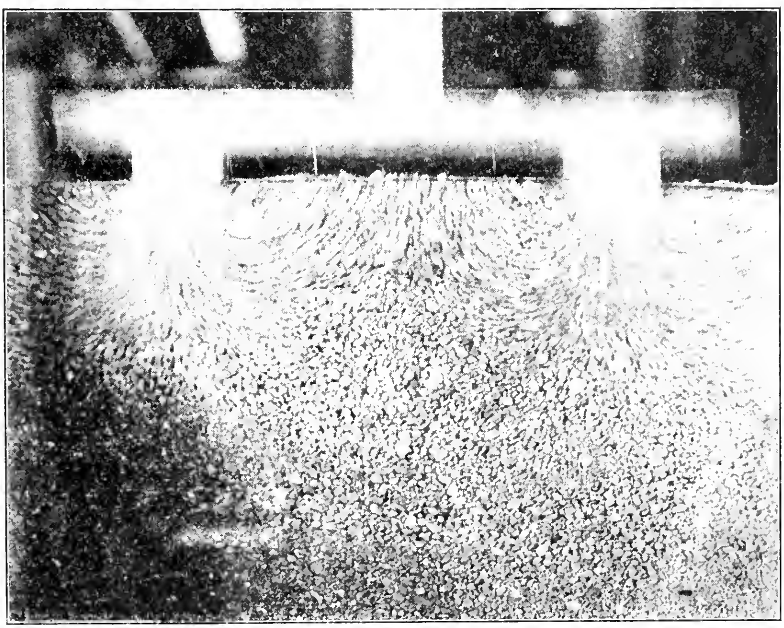


FIG. 73.—LINES OF MOVEMENT OF SAND BALLAST UNDER LOAD.

Illinois in connection with undergraduate thesis work.* Although the experiments were limited to circular bearing areas and therefore are not directly applicable to railroad track, the work proved very instructive and the experience gained was helpful in planning the more elaborate experimental work afterward undertaken for the Joint Committee.

Figs. 72 and 73 are from photographs taken by Messrs. L. N. Fisher and H. F. Wagner in 1912 and included in their thesis. The photographs were made by taking a time exposure of coarse sand behind a plate of glass while a load was being applied to two small blocks (2 by 2 in.). The images of the moving grains are elongated in the direction of motion, giving the appearance of lines of force in a magnetic field. The photographs indicate the paths of flow in the case of the very loose ballast used and, in a general way, indicate the tendencies of ballast movements in track under the action of load.

37.—The Laboratory Experimental Work.—The laboratory experimental work undertaken by the Committee was made in the Laboratory of Applied Mechanics of the University of Illinois. In the attempts which had been made to measure pressures in ballast under regular track conditions, difficulties were met that showed the advisability of conducting experiments in the laboratory where conditions could be controlled and results obtained to establish some of the basic principles of the action of ballast.

Two elevations showing the arrangement of the apparatus used in making the tests are shown in Fig. 74. A reinforced concrete slab 16 by 19 ft. and 12 in. deep supported the ballast. The load was applied to the ties by means of a jack whose upward thrust was carried by I-beams to four $1\frac{7}{8}$-in. steel rods having ends embedded in the concrete slab. The load applied by the jack was distributed to the one, two, or three ties used in the experiments by means of a system of levers. It was possible to divide the load among the ties in any manner desired. The load applied by the jack was measured by a calibrated steel spring. The arrangement of the apparatus can be seen in Fig. 75.

For measuring the intensity of pressure transmitted to various parts of the ballast, the pressure capsule shown in Fig. 76 was used. The following description which was given in the first progress report is here repeated for the convenience of the reader:

The elastic deflection of a thin steel diaphragm is used to measure the amount of pressure applied to the capsule. The pressure to be measured is received on the bearing plate *P*, which has an area of 5 sq. in.; the pressure is transmitted to the thin steel diaphragm *D*, which is fastened by screws around its circumference to the cast-

* An article by Prof. M. L. Enger describing the methods of experimenting and giving the results was published in the following papers: *Engineering Record*, Vol. 73, p. 106, January 22d, 1916; *Railway Age Gazette*, Vol. 60, p. 321, February 18th, 1916; *Engineering and Contracting*, Vol. XLV, p. 53, January 19th, 1916; and *Railway Review*, Vol. 58, p. 129, January 22d, 1916.

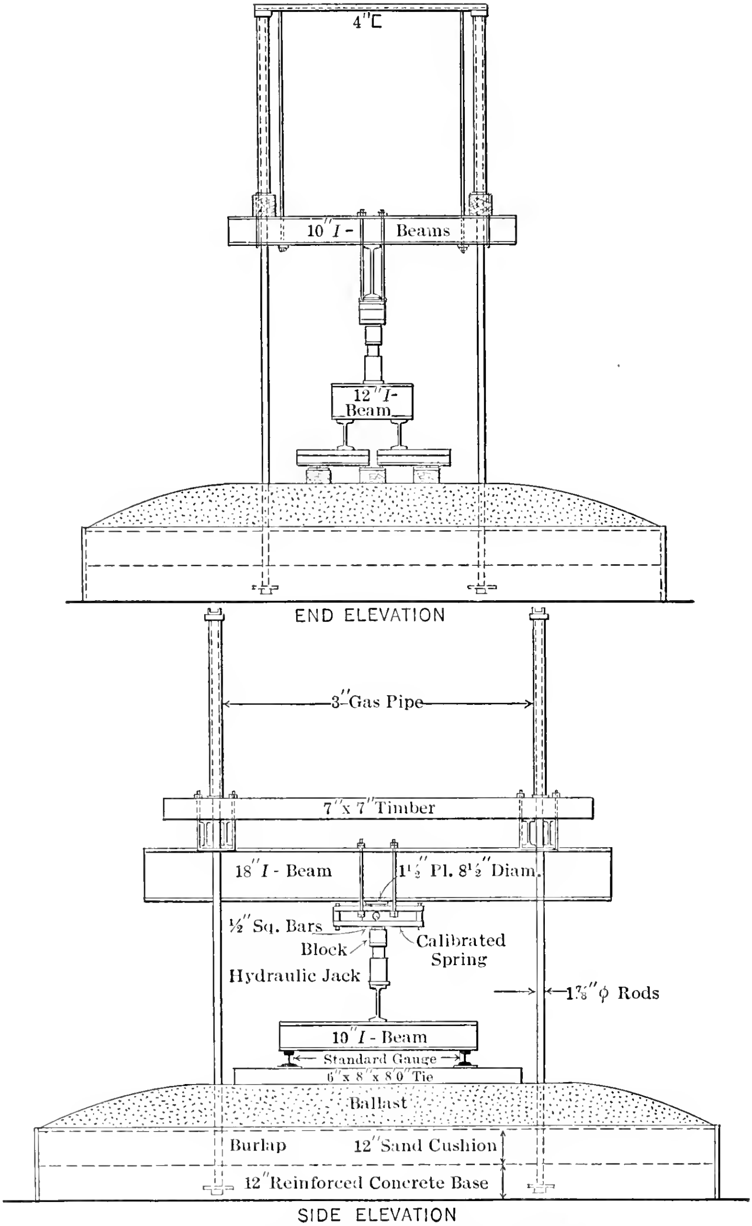


FIG. 74.—APPARATUS USED IN TESTS ON TRANSMISSION OF PRESSURE THROUGH BALLAST.

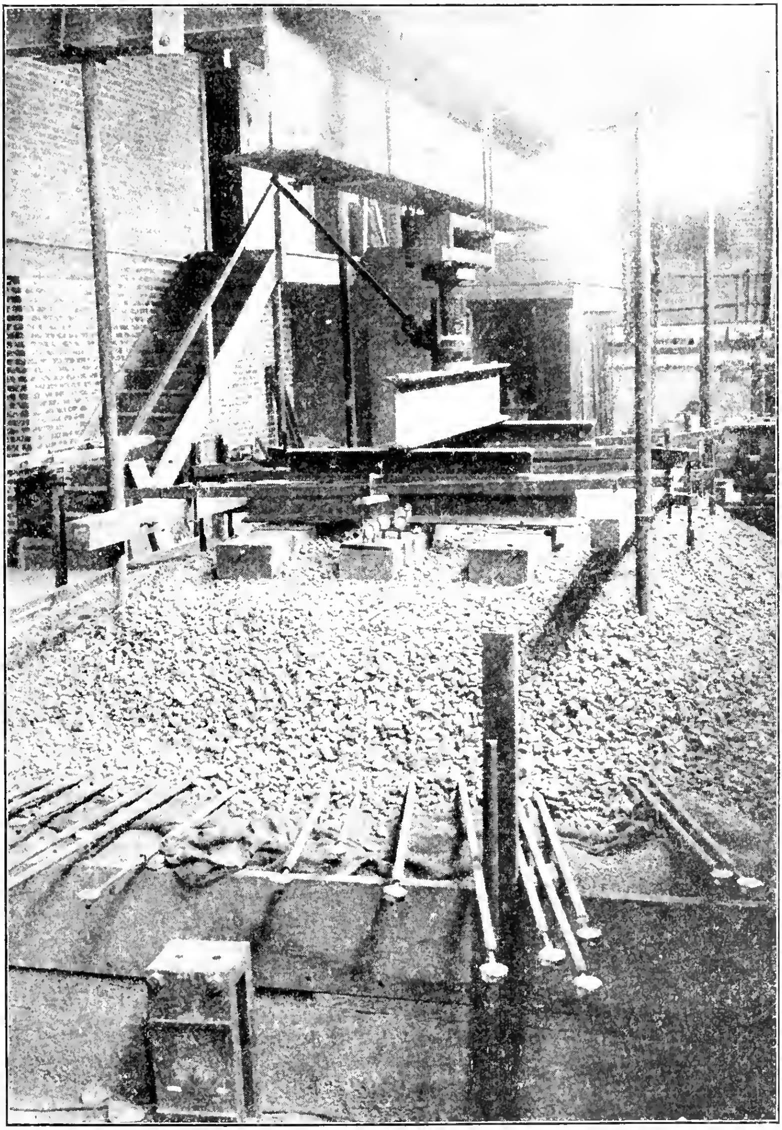


FIG. 75.—APPARATUS USED IN TESTS ON TRANSMISSION OF PRESSURE THROUGH BALLAST.

iron case B. The screw S which fastens the plate P to the diaphragm D is hardened and bears on one knife edge of the small bell-crank lever L which is pivoted at Q. The vertical deflection of the center of the diaphragm is transmitted by the bell-crank lever (magnified about three times) in a horizontal direction to the rod R which slides in guides NN' and is enclosed in a horizontal tube K and finally bears against plunger T of an indicating dial micrometer, whose movement

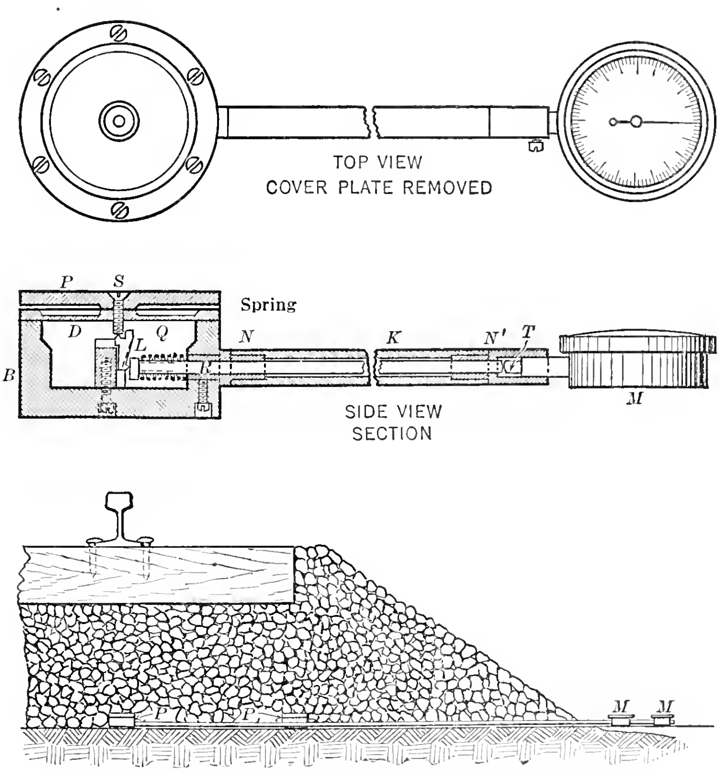


FIG. 76.—PRESSURE CAPSULE AND ITS PLACE IN BALLAST.

is thus a measure of the elastic deflection of the diaphragm D. If the material of the diaphragm is not stressed beyond its elastic limit the deflection of the diaphragm, and the consequent movement of the pointer of the dial micrometer, may be used to measure the load on the plate P. Sand and dirt are prevented from coming between the bearing plate P and the diaphragm by friction tape wrapped around the case of the pressure capsule. Each pressure capsule was calibrated after being taped, by placing it on a platform scale and by means of a

screw clamp applying a series of loads covering the range of its use.

The thin elastic diaphragm is made of hardened steel. The bearing plate serves to take load of any distribution or concentration upon it and to apply this load as a concentrated load at the center of the diaphragm.

There was at first some difficulty due to ballast movements causing the tube to be pulled out of the capsule. Even after making a threaded connection between the tube and capsule there was some trouble from this cause. It was finally entirely overcome by slipping a 1-in. pipe over the tube, protecting it from the pull of the ballast.

38.—Procedure of Tests.—During the progress of the work some changes were made in the making of the tests. The most important changes relate to the disposition of the pressure capsules in the ballast. The locations of the capsules are shown in each case in the figures giving the results of the tests.

In the experiments with the sand ballast, the capsules were placed on the concrete slab and great care was taken in placing the sand around them in order to prevent them from being displaced. After a sufficient quantity of ballast had been placed it was struck off to a level surface at the required depth. After the ties had been placed carefully in the desired position with respect to the capsules, they were loaded five or six times before beginning to take readings. The micrometer dials were then read with no load on the ties. A small load was then applied and readings were again taken. Usually a zero load and three increasing loads were applied. Readings were taken until three consecutive sets of consistent readings were obtained. The greatest load to be applied was determined by: (*a*) the capacity of one or more of the pressure capsules, (*b*) the carrying capacity of the ballast, or (*c*) the capacity of the jack.

In the first test the sand was placed so that it was 6 in. from the bottom of the tie to the top of the capsule. When the experiments with this depth of ballast had been completed the pressure capsules were rearranged and experiments were made with depths of ballast of 9, 18, and 25 in. The ballast was loosened up in each case before additional sand was put on.

Following these tests, the ballast was removed. The capsules were recalibrated and given a different arrangement (see Fig. 77) and were covered with sand ballast to a depth of 12 in. from bottom of tie to top of capsule.

Depths of broken stone ballast of 12 in. and 18 in. were next used. In these experiments a 15-in. sand cushion was placed on the concrete slab and covered with burlap. The capsules were placed on the burlap as shown in Fig. 78. Then the broken stone was carefully placed so as not to disturb the capsules. The experiments were made in the same manner as with sand ballast.

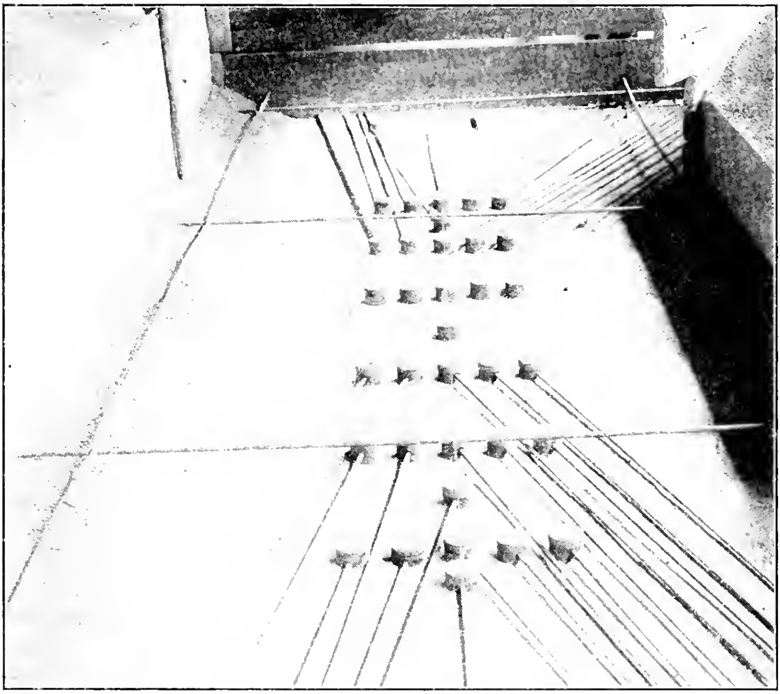


FIG. 77.—ARRANGEMENT OF CAPSULES AND RODS UNDER SAND BALLAST.

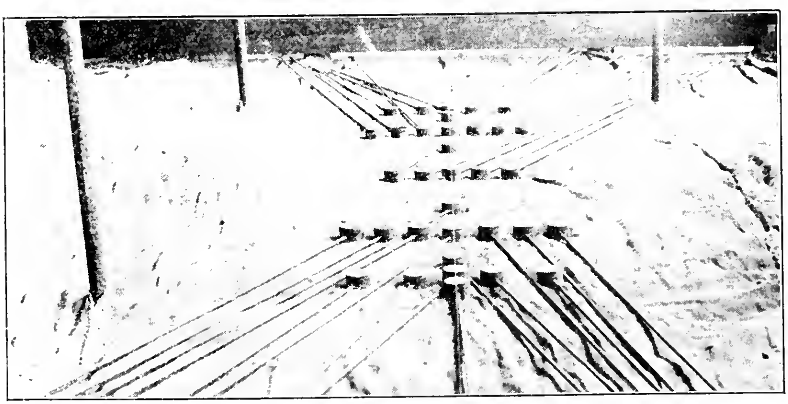


FIG. 78.—ARRANGEMENT OF CAPSULES FOR TESTS WITH BROKEN STONE BALLAST.

Pebble ballast having a depth of 12 in. from tie to capsule was next used. The capsules were recalibrated and were placed on the burlap with a slightly different arrangement than was used in the broken stone ballast.

39.—Results of Tests.—The results of the tests are given in Fig. 79 to 87, presented graphically in order to facilitate comparison and to give the essential information in the most compact form. For example, in Fig. 80 there are given the results of the tests on the transmission of pressure from a single tie through 12 in. of sand ballast. The relative position of the tie and the capsule is shown, and in addition there are curves giving the vertical pressure at various sections. The curves at *AB* represent the averages of the pressures measured by the capsules at *AB* and *LM*. To illustrate, the pressures determined from the readings of the Pressure Capsules 1, 2, 3, and 4 were averaged and are plotted above Capsules 1 and 2. The curves above *CD* represent the average pressures as measured by the capsules on the lines *CD* and *JK*, and the curves above *GH* represent the average pressure measured on *EF* and *GH*. Below the plan view of the tie are plotted curves representing the pressures 12 in. below the center line of the tie. By the manner of plotting all of the curves are symmetrical. The dotted lines in Fig. 80 represent the intensity of pressure when the tie carries a total load of 35 000 lb. The full lines are for a total load of 24 000 lb.

Fig. 79 gives the results of experiments on a single tie with depths of sand ballast of 6, 9, and 18 in., Fig. 80 gives results for sand ballast 12 in. deep when the ordinary 6 by 8-in. by 8-ft. tie is used and also when a tie with a wedge-shaped bottom is used. The wedge was 1½ in. high in the middle of the tie. It will be noted that the pressure is somewhat more widely distributed with the wedge-shaped tie.

Figs. 81, 82 and 83 give the results of the experiments for depths of sand ballast of 9, 18, and 25 in. when the ties are equally loaded and when the middle tie carries twice the load carried by either of the outside ties.

Fig. 84 gives the results of the experiments for 12 in. of broken stone ballast and for the same depth of pebble ballast. The broken stone used was the standard limestone ballast material furnished by the Illinois Central Railroad. The pebble ballast consisted of pebbles ranging in size from about ¼ in. to 1½ in. and was free from sand. It will be noted that the results of experiments with rock ballast are more erratic than with pebbles or with sand. This was to be expected because a short chain of the large grains may bring a heavy pressure on a capsule, or it may miss it entirely. When average pressures are taken there is a surprising similarity in the distribution of pressure through sand, pebble and broken stone ballast.

Fig. 85 shows the distribution of pressure through 12 in. of broken stone when the load is carried on a 6 by 10-in. by 8-ft. tie with the 10-

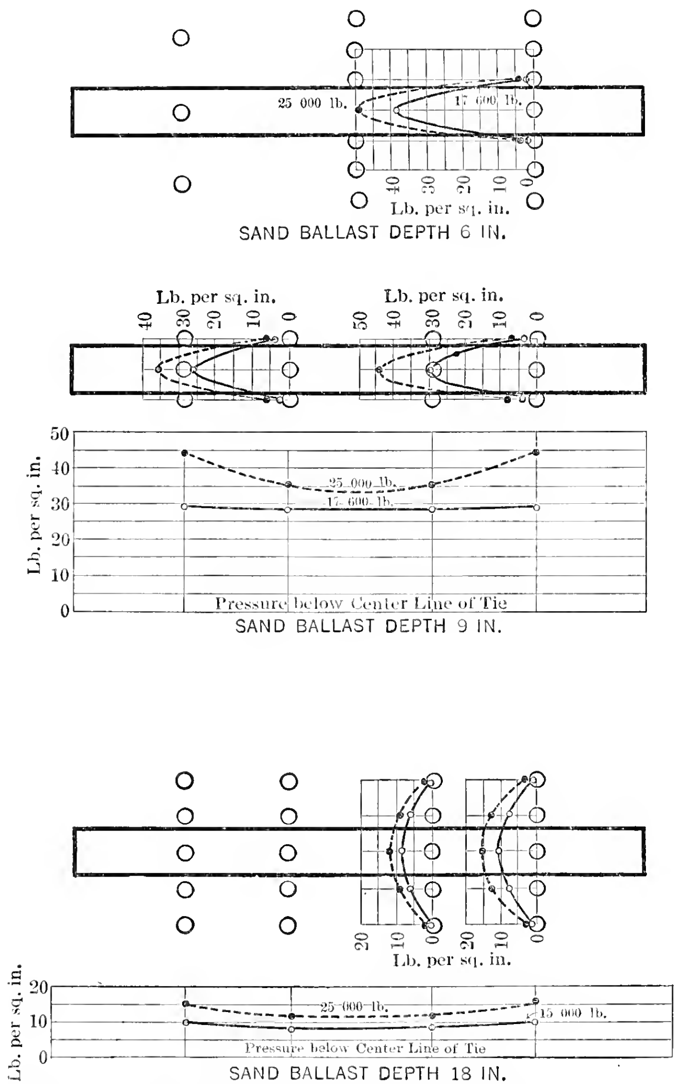


FIG. 79.—DISTRIBUTION OF PRESSURE AT DEPTHS OF 6, 9, AND 18 IN. OF SAND BALLAST BELOW A SINGLE TIE.

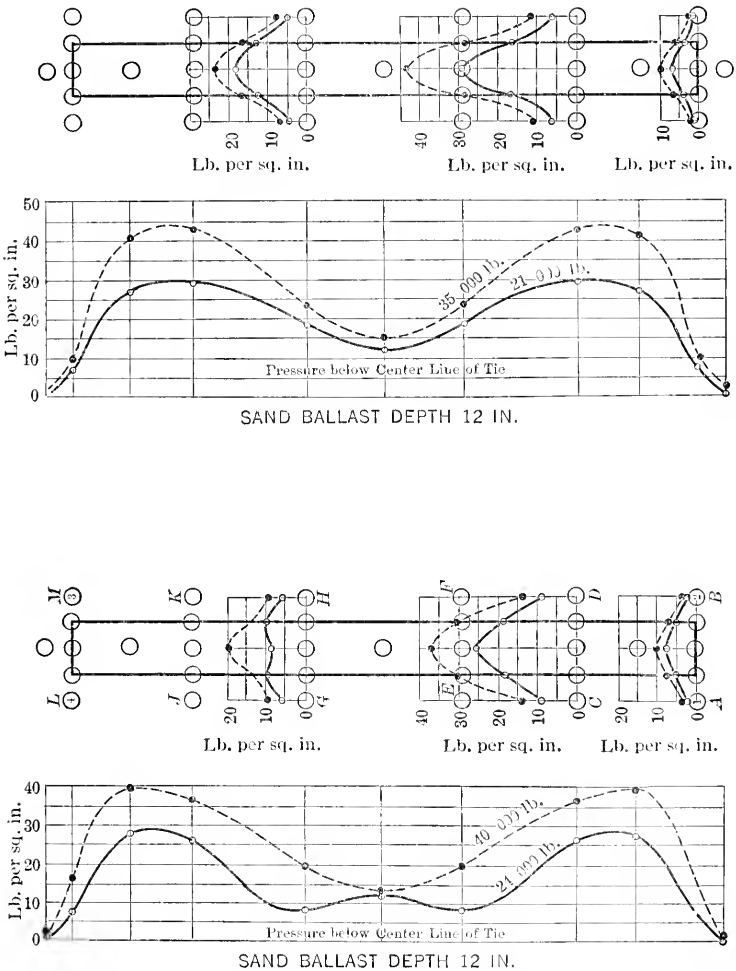
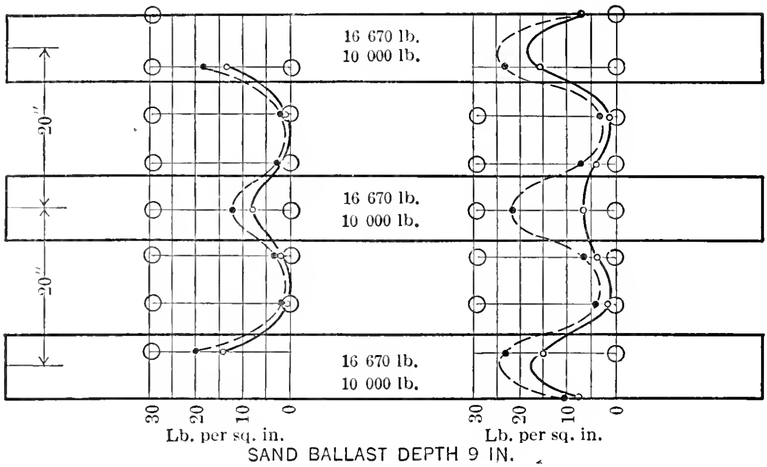


Fig. 80.—Distribution of Pressure at a Depth of 12 In. of Sand Ballast for a Single Ordinary Tie and a Single Tie with Wedge-Shaped Bottom.



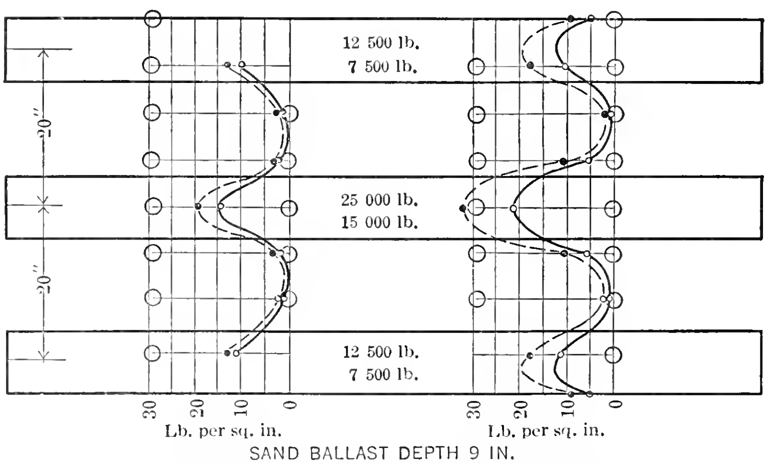
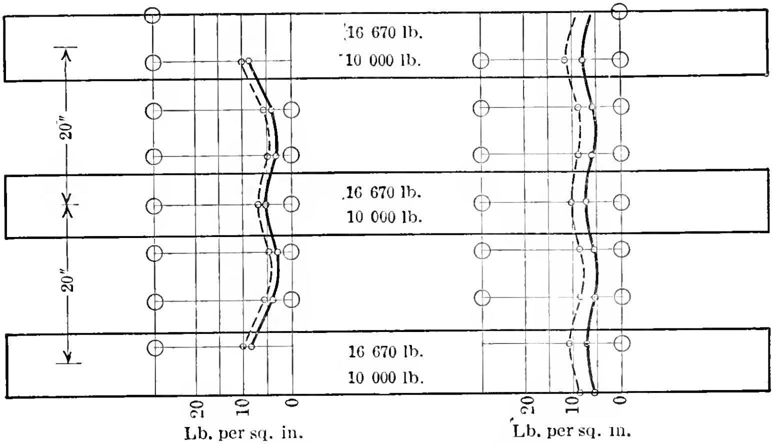
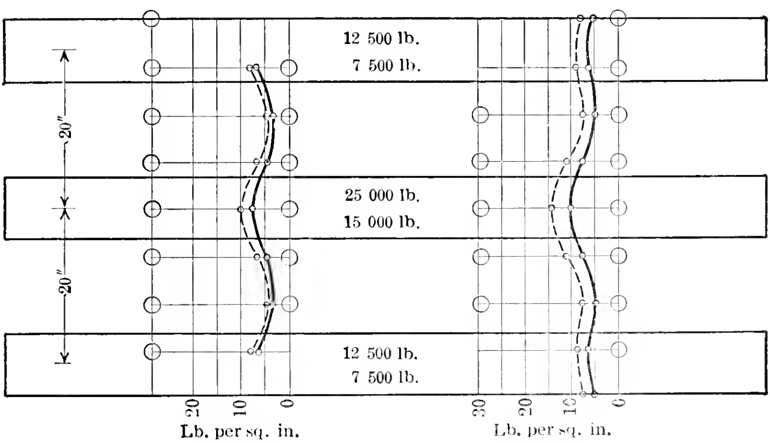


FIG. 81.—DISTRIBUTION OF PRESSURE AT A DEPTH OF 9 IN. OF SAND BALLAST BELOW THREE TIES. EQUAL AND UNEQUAL LOADS ON TIES.

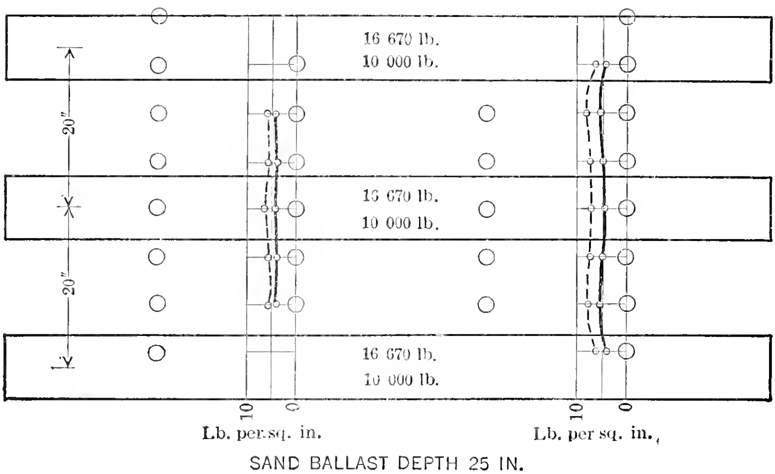


SAND BALLAST DEPTH 18 IN.



SAND BALLAST DEPTH 18 IN.

FIG. 82.—DISTRIBUTION OF PRESSURE AT A DEPTH OF 18 IN. OF SAND BALLAST BELOW THREE TIES. EQUAL AND UNEQUAL LOADS ON TIES.



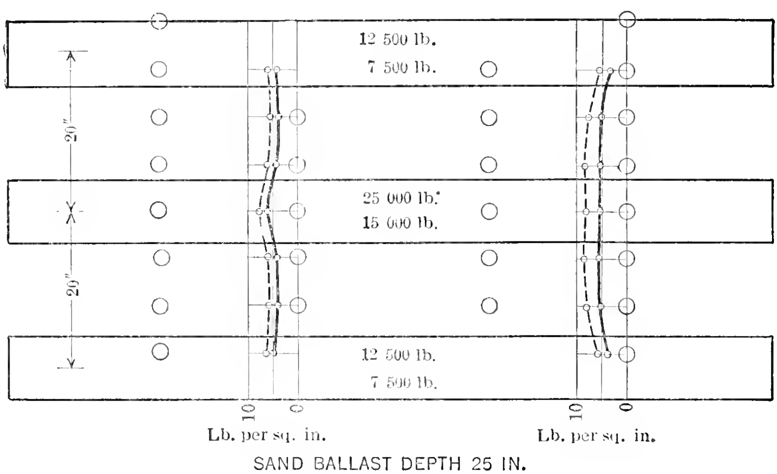


FIG. 83.—DISTRIBUTION OF PRESSURE AT A DEPTH OF 25 IN. OF SAND BALLAST BELOW THREE TIES. EQUAL AND UNEQUAL LOADS ON TIES.

in. face horizontal, and a 6 by 8-in. by 8-ft. tie with the 6-in. face horizontal.

Fig. 86 shows the distribution of pressure through 18 in. of broken stone ballast when three loaded ties are used and also when all of the load is carried on one tie.

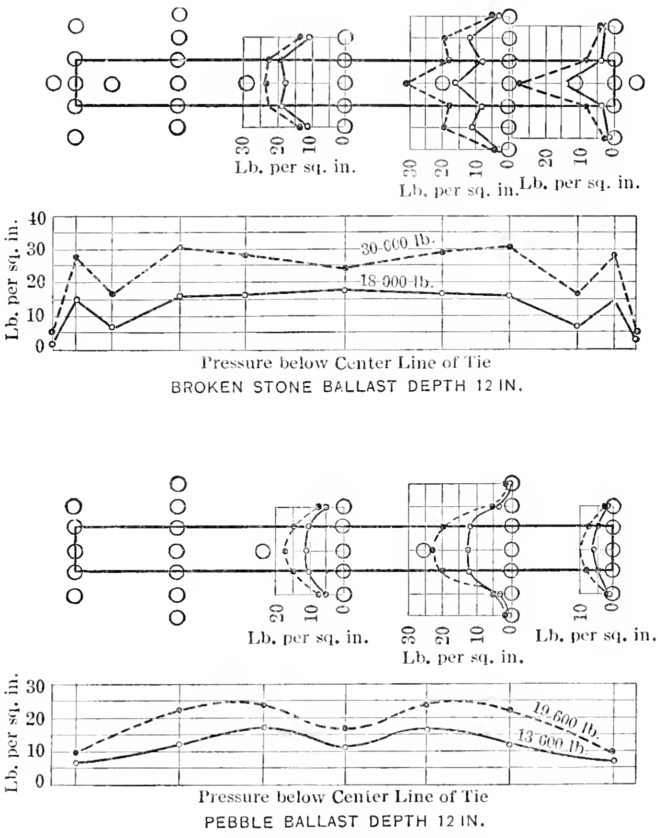


FIG. 84.—DISTRIBUTION OF PRESSURE AT A DEPTH OF 12 IN. OF BROKEN STONE AND 12 IN. OF PEBBLE BALLAST BELOW A SINGLE TIE.

Fig. 87 shows the distribution of pressure on the bottom of a tie which rests on pebble ballast, and also the pressure measured simultaneously at a depth of 12 in. below the tie. The tie was prepared by embedding the capsules in the tie. The circular bearing plate of the capsule had been replaced with rectangular bearing plates, 3 by 1 in., and the surface of these was left flush with the bottom of the tie. The positions of the pressure capsules in the tie are indicated in the figure.

C.—Discussion of Results of Tests.

40.—Diagrams of Average Pressure and Use of Superposition of Pressures.—In order to eliminate the variations in pressure due to flexibility of tie and other causes, for the study of the data, the pressures measured by all capsules located at the same distance from the longitudinal axis of the tie have been averaged. Using this method the diagrams in Fig. 88 have been drawn; they show the pressure at different depths and different distances from the center line of the tie

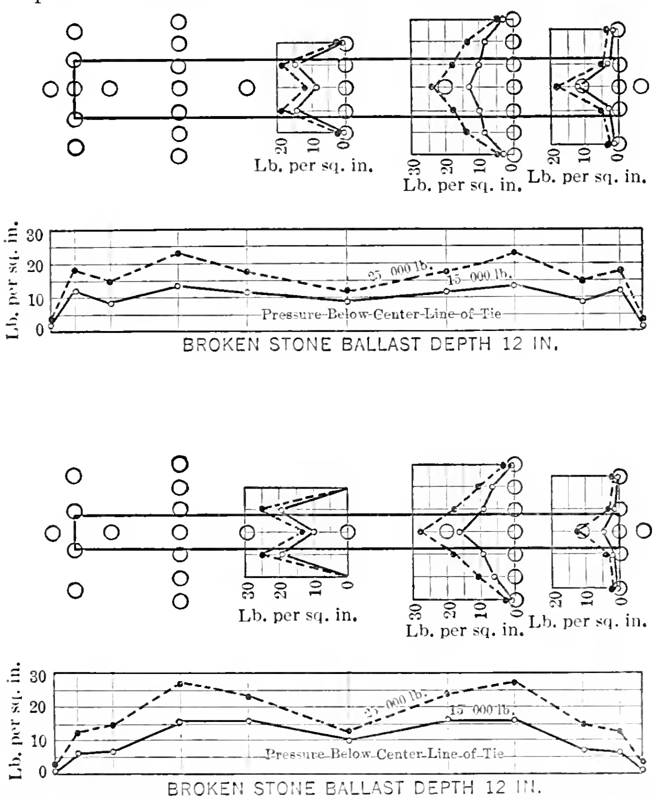


FIG. 85.—DISTRIBUTION OF PRESSURE AT A DEPTH OF 12 IN. OF BROKEN STONE BALLAST BELOW A TIE 10 IN. WIDE AND BELOW ONE 6 IN. WIDE.

when a single tie is loaded, as given by the averages of the readings. The pressure is expressed as a percentage of the average intensity of pressure over the tie. The average result for the three loads has been used. In addition, the highest and the lowest pressure measured by any capsule is shown. Using the same method, the results obtained in tests with three ties have been plotted by full lines in Fig. 89 to 93. There have also been plotted the dotted lines marked "superposed pressure curve".

This method of superposition considers that at a given point the combined effect of several ties is the sum of the effects of the individual ties. The effect of a tie at a given point was obtained from the curves of Fig. 88. It will be noted that the superposed pressure curves agree

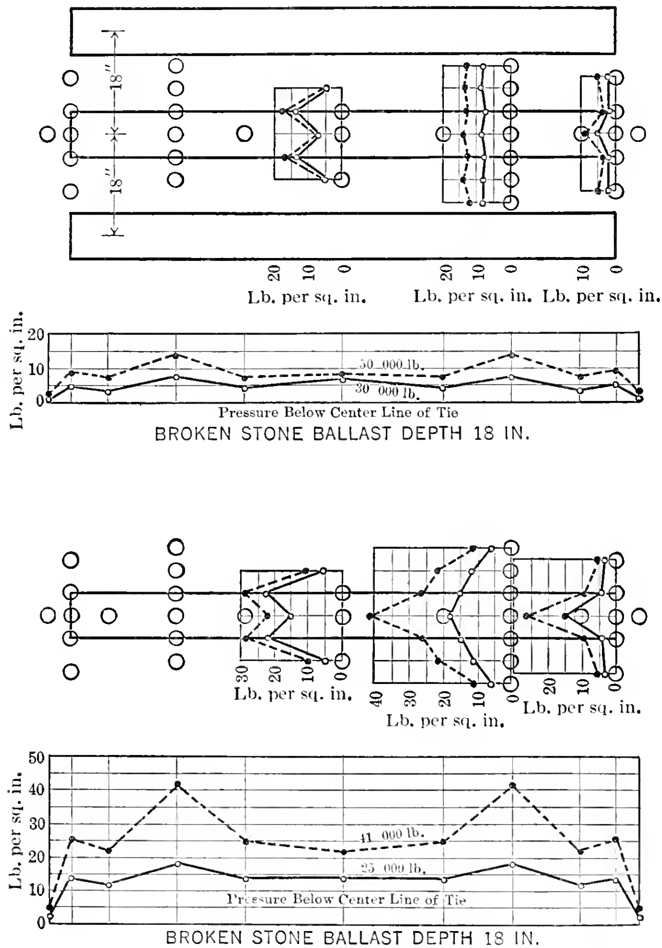


FIG. 86.—DISTRIBUTION OF PRESSURE AT A DEPTH OF 18 IN. OF BROKEN STONE BALLAST BELOW THREE TIES AND BELOW A SINGLE TIE.

with the experimental curves reasonably well, indicating that the vertical pressure at any given point in the ballast is the sum of the vertical pressures which would be caused at that point by adding the pressures from the ties considered separately. By means of this principle, which seems to be established by these experiments, the results

of the experiments with a single tie may be used to determine the pressure in ballast under any condition of the spacing and loading.

41.—Comparison of Pressure Distributions in Different Kinds of Ballast.—An examination of the pressure curves for the sand, broken stone, and pebble ballasts will show that there are no decided differences in the distribution of the pressure at a given depth except that the results found with sand are more concordant than those with the coarser ballast. It may be concluded that the laws of distribution of pressure

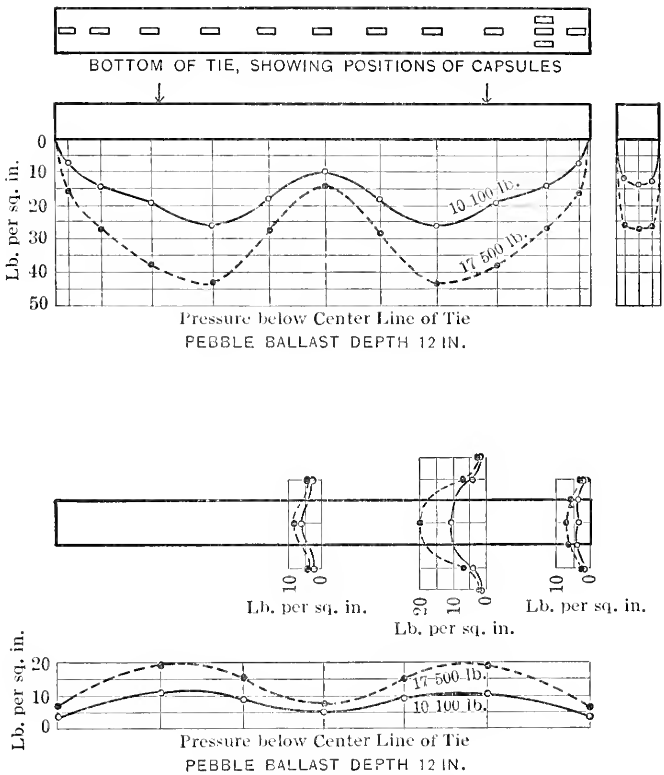


FIG. 87.—DISTRIBUTION OF PRESSURE AT A DEPTH OF 12 IN. OF PEBBLE BALLAST BELOW A SINGLE TIE AND AT THE BOTTOM OF THE TIE.

through ballast (non-cohesive granular material) are practically the same for the various kinds of ballast.

It should be borne in mind that the foregoing statement applies to distribution of pressure only; ultimate bearing load, action under vibration, and other properties of ballast will differ materially.

42.—Intensity of Pressure at Different Depths Below Center Line of Tie.—The intensity of pressure below the center line of the tie at various depths has been given in Fig. 88. Using values taken from this

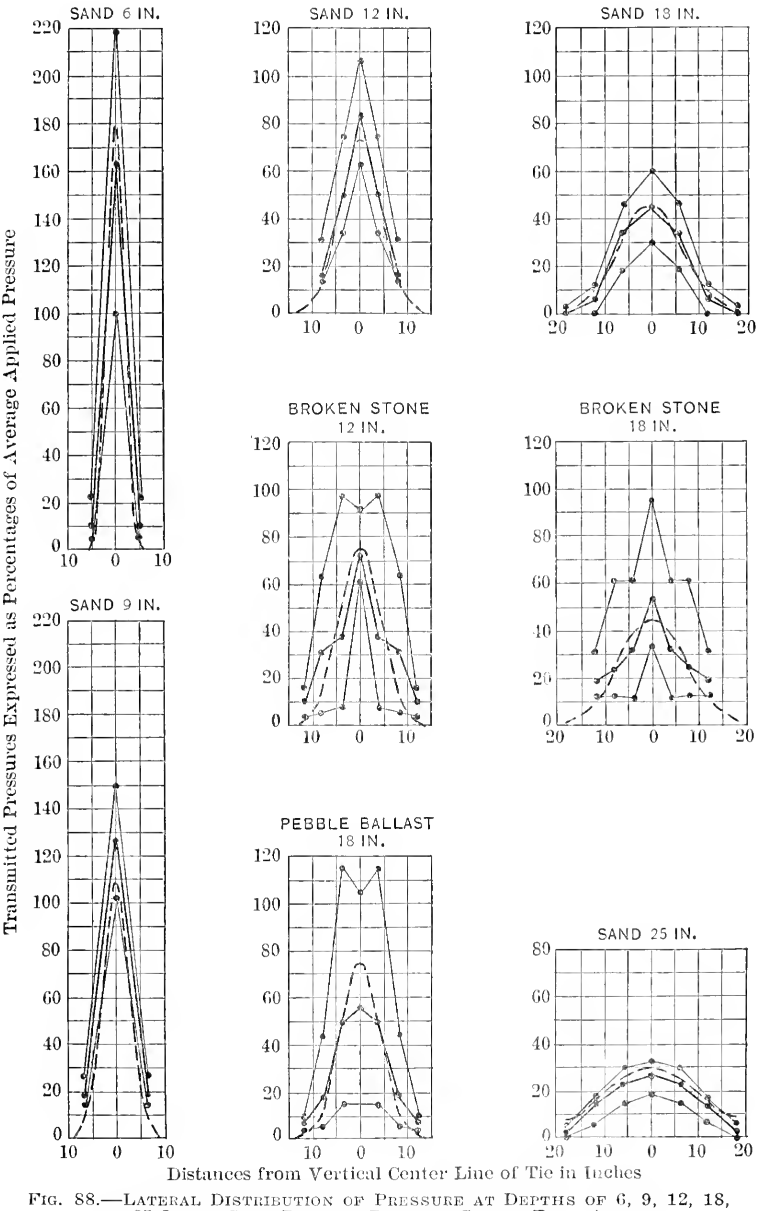


FIG. 88.—LATERAL DISTRIBUTION OF PRESSURE AT DEPTHS OF 6, 9, 12, 18, AND 25 IN. OF SAND BALLAST BELOW A SINGLE TIE. AVERAGE RESULTS OF TESTS.

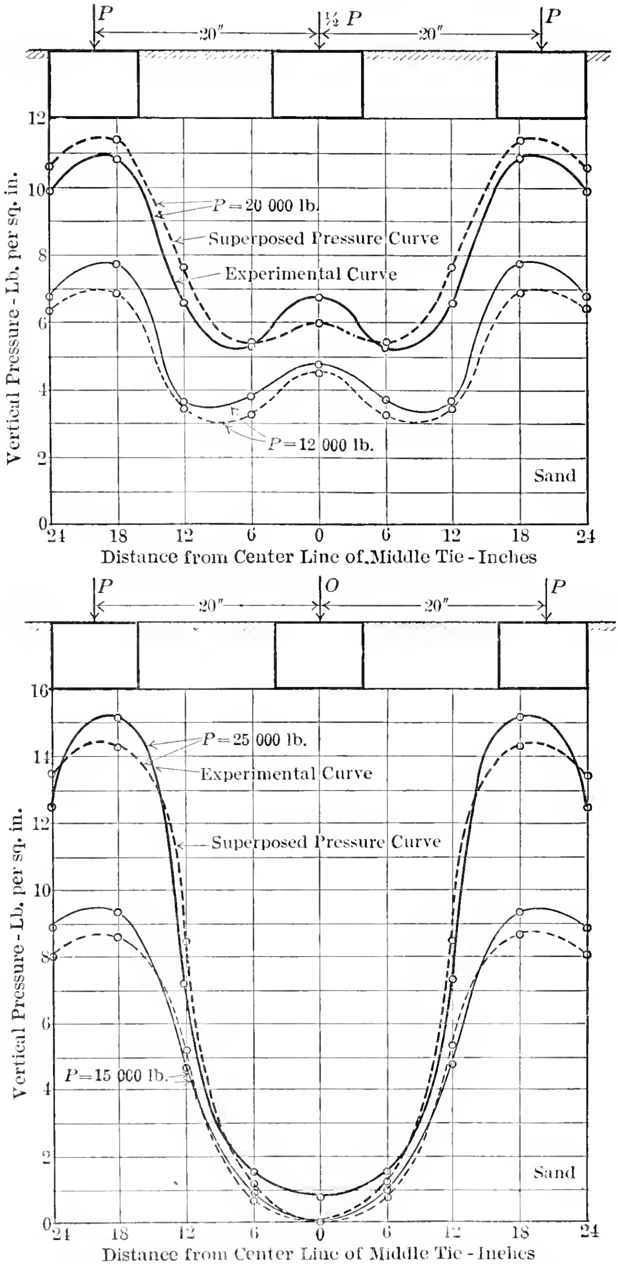


FIG. 89.—LATERAL DISTRIBUTION OF PRESSURE AT A DEPTH OF 18 IN. OF SAND BALLAST BELOW THREE TIES AND VALUES OBTAINED BY SUPERPOSING RESULTS FOUND WITH A SINGLE TIE.

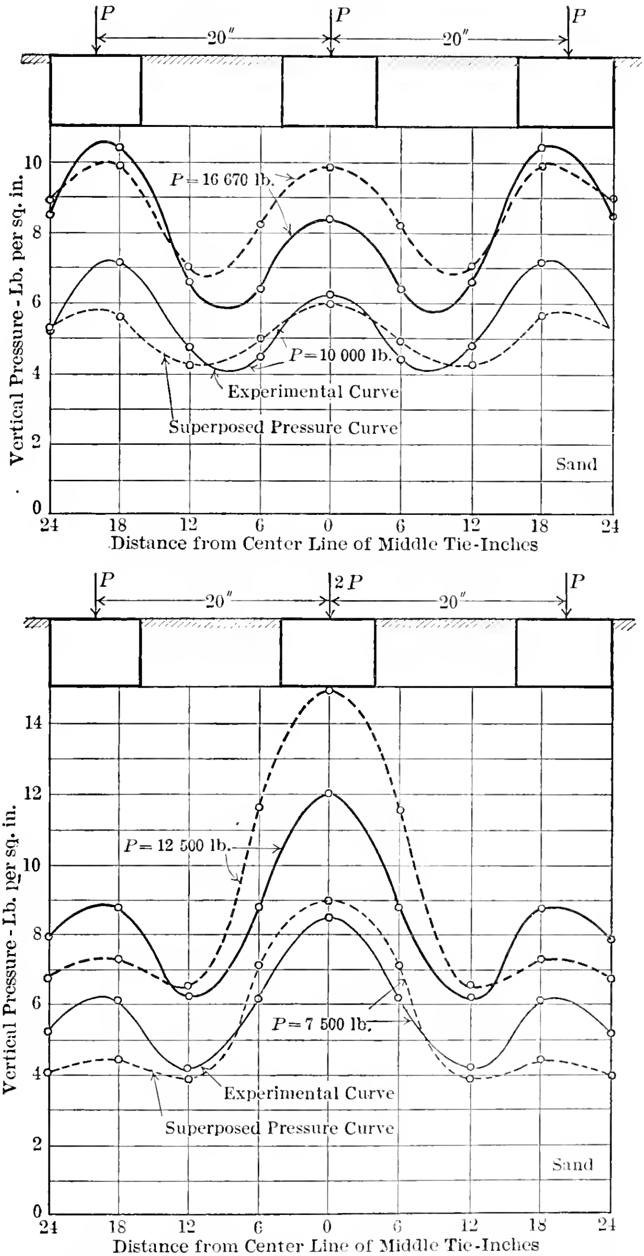
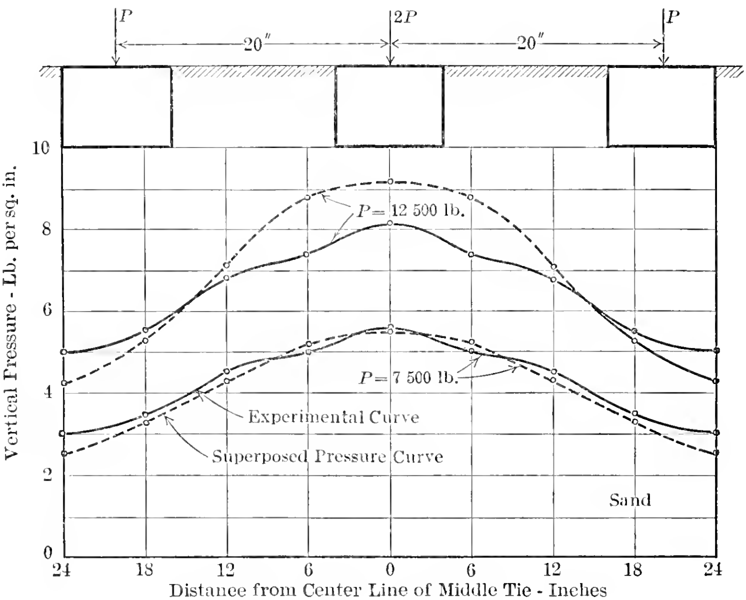


FIG. 90.—LATERAL DISTRIBUTION OF PRESSURE AT A DEPTH OF 18 IN. OF SAND BALLAST BELOW THREE TIES AND VALUES OBTAINED BY SUPERPOSING RESULTS FOUND WITH A SINGLE TIE.



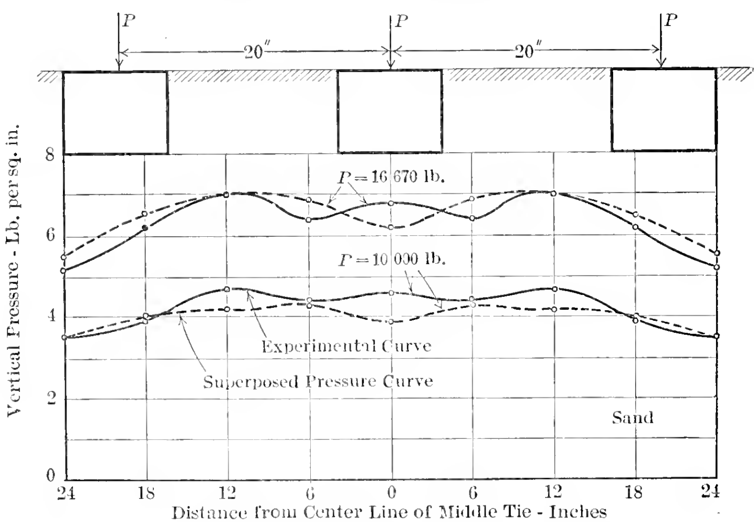
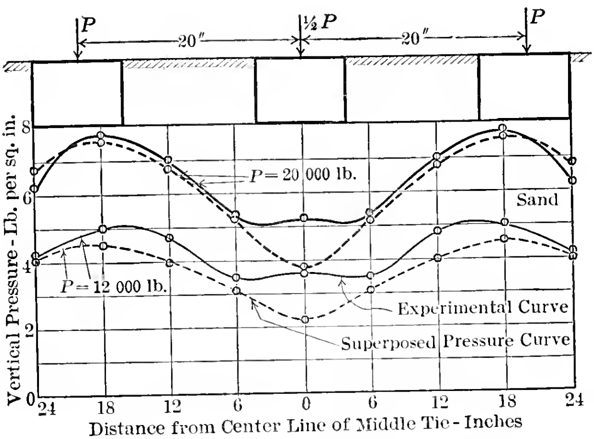


FIG. 91.—LATERAL DISTRIBUTION OF PRESSURE AT A DEPTH OF 25 IN. OF SAND BALLAST BELOW THREE TIES AND VALUES OBTAINED BY SUPERPOSING RESULTS FOUND WITH A SINGLE TIE.



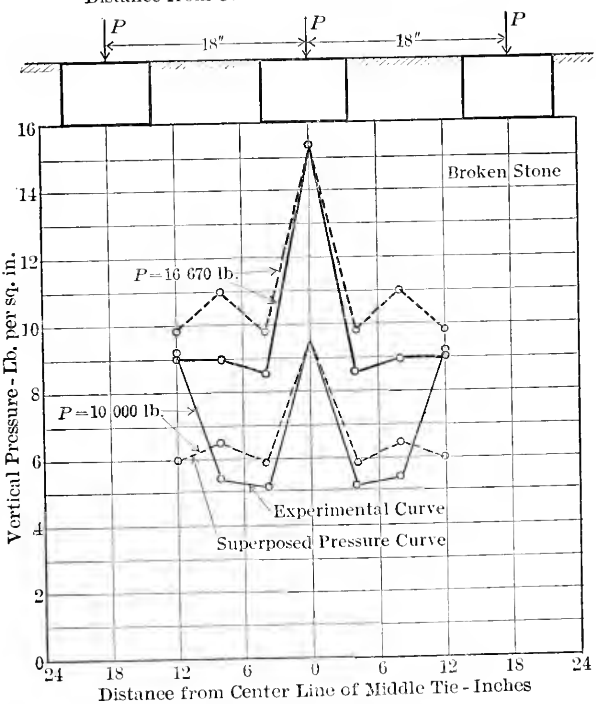


FIG. 92.—LATERAL DISTRIBUTION OF PRESSURE AT A DEPTH OF 25 IN. OF SAND BALLAST AND AT A DEPTH OF 12 IN. OF BROKEN STONE BALLAST BELOW THREE TIES AND VALUES OBTAINED BY SUPERPOSING RESULTS FOUND WITH A SINGLE TIE.

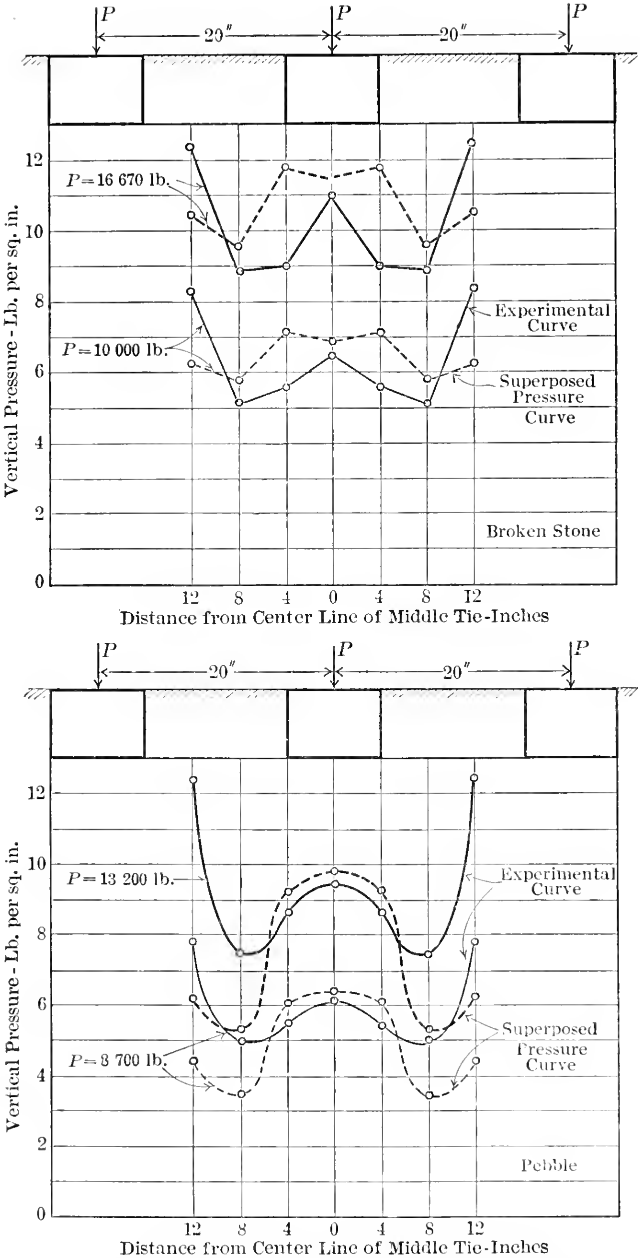


FIG. 93.—LATERAL DISTRIBUTION OF PRESSURE AT A DEPTH OF 18 IN. OF BROKEN STONE BALLAST AND OF 12 IN. OF PEBBLE BALLAST BELOW THREE TIES AND VALUES OBTAINED BY SUPERPOSING RESULTS FOUND WITH A SINGLE TIE.

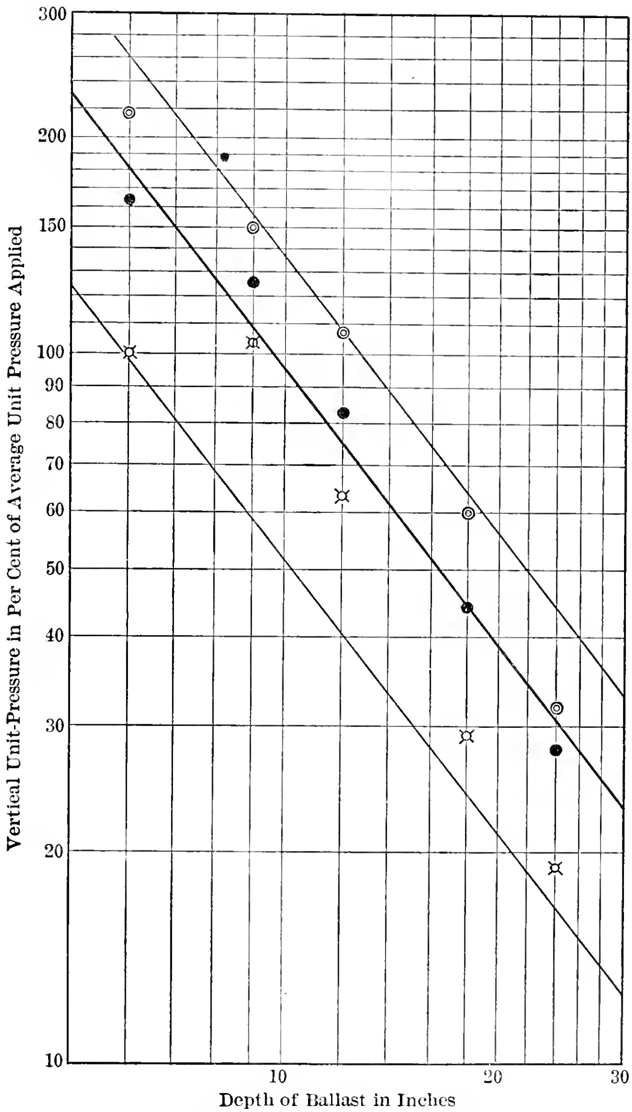


FIG. 94.—RELATION OF INTENSITY OF PRESSURE UNDER CENTER LINE OF TIE TO DEPTH BELOW BOTTOM OF TIE. LOGARITHMIC SCALE.

figure Fig. 94 has been drawn to express by logarithmic co-ordinates the relation between the unit-pressure at points below the center line of tie and the corresponding depth of ballast. The ordinate of a plotted point represents the pressure at a point below the center line of the tie expressed as a percentage of the average pressure over the bottom of the tie; the abscissa represents the depth of ballast at the point. The maximum and minimum observed intensities of pressure have also been plotted. A straight line whose equation is

$$p_c = \frac{16.8\ p_a}{h^{1.25}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (25)$$

has been drawn and fits the observations fairly well within the range of the tests, although for depths less than 4 in. and more than 30 in. the results are too high. In this equation p_a is the average pressure over the tie and p_c the pressure at the given point directly below the center line of tie, both in pounds per square inch, and h is the vertical distance in inches below the bottom of the tie. It should be noted that this expression was obtained from tests with ties 8 in. wide.

43.—Distribution of Pressure Over a Horizontal Plane.—It is desired to obtain an equation for the intensity of pressure at any point (x, h) in the ballast, developed by a tie carrying load, which shall agree with the values of the pressure found by experiment.

From the discussion in Article 30 on "Paths of Pressure and Laws of Distribution of Pressure", it was concluded that the distribution of the intensity of vertical pressure on any horizontal plane due to a load p_a on a narrow strip would be represented by Equation (15) of the form

$$p = \frac{k\ p_a}{\sqrt{\pi}}\ e^{-k^2x^2}.$$

Since a tie may be considered to be made up of a number of narrow strips, the pressure in the ballast below a tie may be considered as a composite of the pressures due to the strips. It is found that the composite pressures in the ballast below a tie may also be represented by an equation of the form of Equation (15) except at small depths. The equation may then be written

$$p = \frac{K\ P_a}{\sqrt{\pi}}\ e^{-K^2x^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (26)$$

p being the intensity of vertical pressure on a horizontal plane at a distance x from the vertical center line of the tie due to a load p_a per inch of length of tie. For an 8-in. tie

$$P_a = 8\ p_a$$

in which p_a is the average pressure on bottom of tie in pound per square inch. Hence

$$p = \frac{8\ K\ p_a}{\sqrt{\pi}} e^{-K^2 x^2}$$

When $x = 0$

$$p = p_c = \frac{8\ K\ p_a}{\sqrt{\pi}}$$

In the preceding article it was found from the results of experiments with 8-in. ties in Equation (25) that

$$p_c = \frac{16.8\ p_a}{h^{1.25}}$$

Equating the values of p_c and solving for K:

$$K = \frac{2.1\sqrt{\pi}}{h^{1.25}}$$

Substituting this value of K in the equation and changing from the base e to the base 10, the following empirical equation for p is obtained

$$p = \frac{16.8\ p_a}{h^{1.25}} (10)^{-6.05\frac{x^2}{h^{2.5}}} \qquad (27)$$

in which p_a is the average intensity of pressure over the tie per square inch, and p is the pressure per square inch at a point on a horizontal plane h in. below the tie and x in. from the center line of the tie. The equation applies only to an 8-in. tie and is applicable for depths from about 4 in. to about 30 in.

The dotted lines in Fig. 88 represent the pressures as determined by Equation (27). It will be seen that the agreement between the experiments and the equation is fairly good.

44.—Contours of Equal Vertical Unit-Pressure.—From the results of the tests it is possible to draw the contours of equal vertical unit-pressure beneath one or more loaded railroad ties. Fig. 95 shows the contours of pressure beneath a single 6 by 8-in. by 8-ft. tie. The contours are designated by percentages of the average pressure applied to the ballast by the tie. In Figs. 96, 97 and 98, contours of equal vertical pressure are shown beneath a series of equally loaded ties for three different tie spacings. It will be noted that in general the vertical pressures become nearly constant at a depth equal to the tie spacing. It should be added that in determining the contours the principle of superposition and the laws of distribution of pressure given by the equations already derived have been useful. These laws may be applied to conditions not covered by the experimental work.

45.—Lines of Pressure.—In Article 30 on "Paths of Pressure and Law of Distribution of Pressure", it was concluded that a pressure p_a per unit length applied to a long narrow strip will develop an intensity

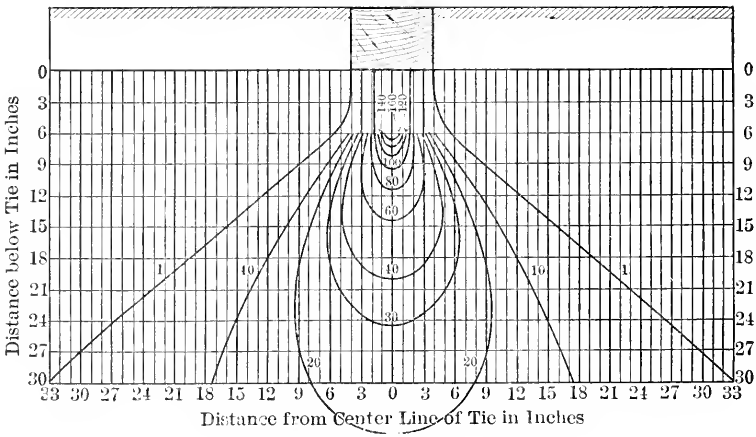


FIG. 95.—LINES OF EQUAL VERTICAL PRESSURE IN BALLAST FOR LOAD ON A SINGLE TIE.

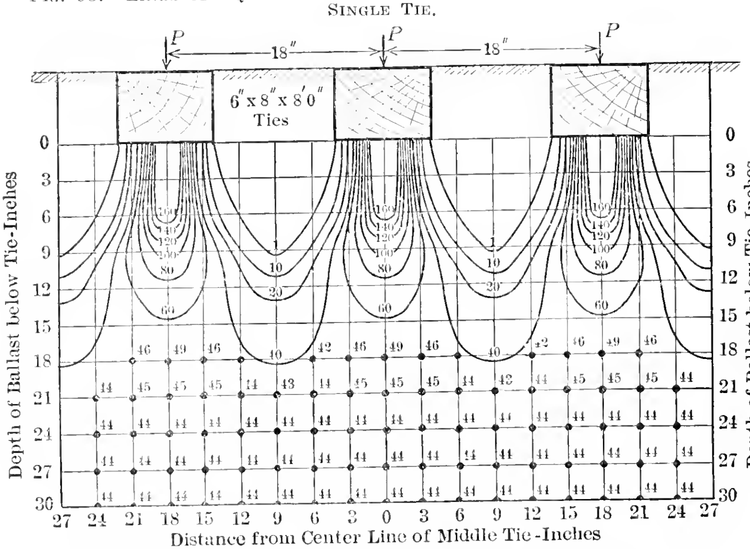


FIG. 96.—LINES OF EQUAL VERTICAL PRESSURE IN BALLAST FOR EQUAL LOADS ON TIES. SPACING 18 IN., CENTER TO CENTER.

of pressure p on a horizontal plane a distance h below the loaded strip and at a distance x from the line of action of the applied load p_a, in accordance with Equation (15) as follows:

$$p = \frac{k\,p_a}{\sqrt{\pi}}\,e^{-k^2x^2}.$$

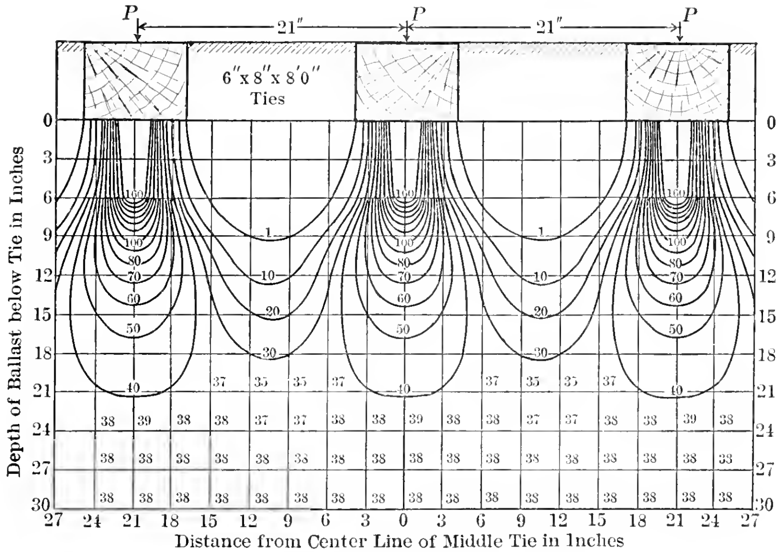


FIG. 97.—LINES OF EQUAL VERTICAL PRESSURE IN BALLAST FOR EQUAL LOADS ON TIES. SPACING 21 IN., CENTER TO CENTER.

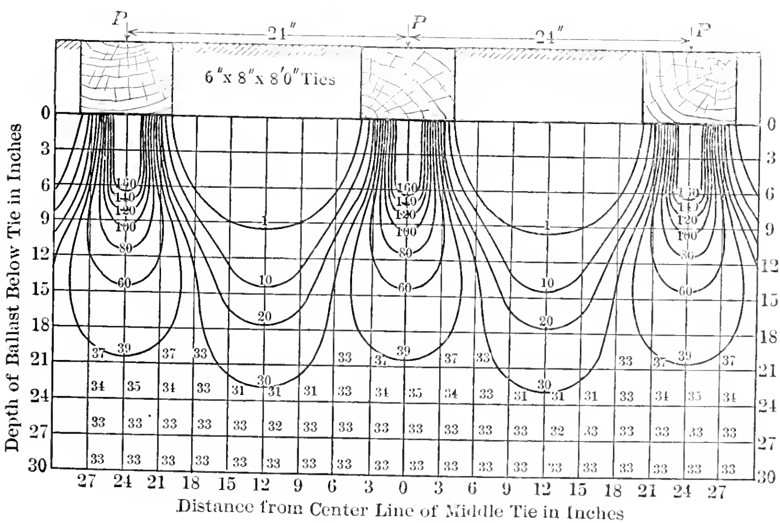


FIG. 98.—LINES OF EQUAL VERTICAL PRESSURE IN BALLAST FOR EQUAL LOADS ON TIES. SPACING 24 IN., CENTER TO CENTER.

In this equation k is a function of the depth h and must be determined by experiment.

The bottom of the tie may be considered to be divided into a number of narrow strips carrying loads of varying intensity and direction, each producing pressures in the ballast in accordance with the equation. At any point in the ballast the intensity of pressure will be equal to the sum of the pressures from the various strips into which the tie is divided.

In Article 31 it was shown that the distribution of pressure in the ballast due to a load on a narrow strip may be represented by lines which were designated lines of pressure.

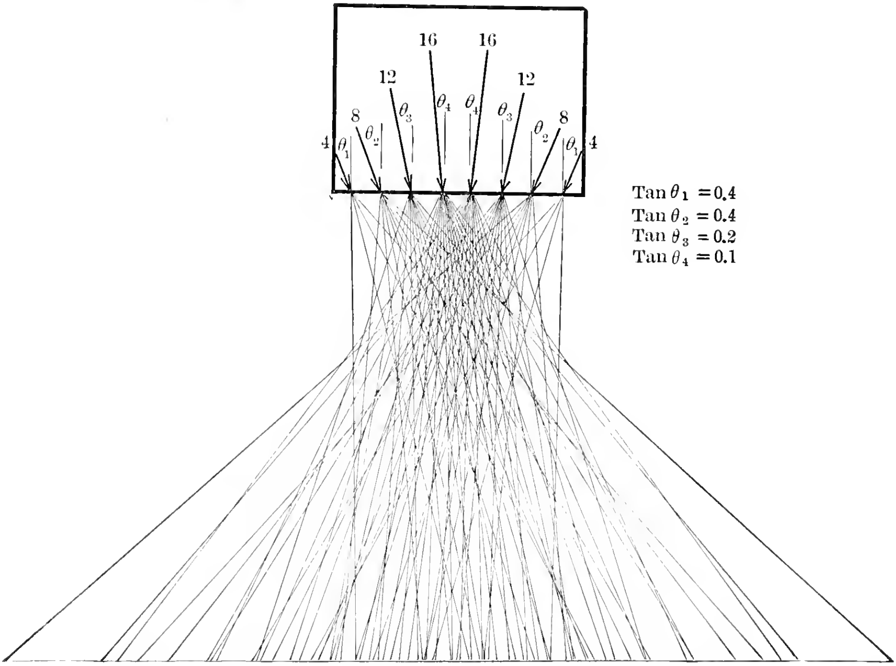


FIG. 99.—DIAGRAMMATIC REPRESENTATION OF LINES OF PRESSURE FOR A TIE 8 IN. WIDE.

After many trials it was found that for dimensions in inches Equation (15) may be written

$$p = 1.23 \frac{p_a}{h} (10)^{-2.06 \left(\frac{x}{h}\right)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (28)$$

Taking the directions and intensities of the pressures p_a on the strips as indicated in Fig. 99, the pressures thus found in the ballast agree quite closely with the values determined in the experiments.

The lines of pressure determined from Equation (28) are straight lines, and were laid out in the following manner: The distribution of

pressure at a depth of 24 in. for the given value of p_a on a given strip was calculated by Equation (28). The results were then plotted on cross-section paper to a large scale using unit-pressures as ordinates and distances from the line of action of the applied pressure as abscissas. The area under the curve was divided into parts each representing 1 lb. and the abscissas of the centroids of such areas were determined. In making the desired division of the area it was found convenient to plot a mass curve beginning at the center line. From the center of the given strip on the tie, a line was drawn in the direction of the applied pressure p_a and at a distance representing 24 in. a perpendicular line was drawn. Upon this perpendicular the abscissas determined above were plotted. Straight lines through these points and the middle of the strip therefore represent lines of pressure of 1 lb. each. The number of such lines passing through a width of 1 in. on a horizontal plane represents the intensity of pressure.

TABLE 19.—Calculated and Experimental Values of Unit-Pressure at Various Points Below a Single Tie. Average Load on Tie, 100 Lb. per Sq. In.

h	x	Calculated p	Experimental p
6	0	161	163
9	0	106	126
12	0	75	83
12	4	47	50
12	8	12	16
18	0	50	45
18	6	30	34
18	10	15	16
18	15	5	4
24	0	37	31
24	10	18	17

Figs. 99 and 100 were plotted in the manner described, Fig. 99 representing the 1-lb. lines of pressure when the average load on the tie is 10 lb. per sq. in. and Fig. 100 when the average load is 100 lb. per sq. in., the only difference being that there are ten times as many lines in the last case. At any point in the ballast the number of lines in 1 in. of width will then represent the number of pounds of pressure per square inch at that point. As a line may represent any intensity of pressure (pounds being used only as an illustration) both figures may be considered to represent the relative distribution of pressure for any given load on the tie.

The vertical unit-pressure at any point may be determined with greater accuracy by substituting for x and h in Equation (28) the values of x_1, and h_1, found by means of Equations (23) and (24) for each unit strip on the tie, and adding the results. The results

of some such calculations are given in Table 19, a width of tie of 8 in. being used, and experimental results are given for comparison.

It will be seen that the distribution of pressure found in the experiments may be accounted for by the superposition of pressures of differing intensities and inclinations over the bottom of the tie.

The method of lines of pressure, in conjunction with the variation of pressure beneath the tie, supplies explanations of the concentration and distribution of pressure in the ballast.

46.—General Discussion.—The following observations summarize some of the results of the tests and analysis and bring out in part the phenomena attending the transmission of pressure from the tie through the ballast.

The bearing pressure of the tie varies in intensity from its edge to its middle line; the maximum intensity is dependent upon the intensity of pressure developed at the edge. A variation in intensity exists also along the length of the tie.

The pressures which react from the lower face of the tie act in other than vertical lines, the greatest variation from the vertical direction being at the edge of the tie.

There is a concentration of pressure a short distance below the tie, say, at 3 to 4 in., and the intensity of pressure in the ballast at such a depth is greater than exists at the bottom of the tie.

For the tie of ordinary width the intensity of pressure at a depth of 6 in. and the distribution of vertical pressure over a horizontal plane at this depth do not differ greatly from those existing immediately under the tie. The directions of the pressures are not the same. At or below this depth the distribution of pressure laterally begins, with a consequent decrease in maximum intensity of pressure, and the change becomes more apparent as the depth increases.

The foregoing relates to the transmission of pressure from a single tie. For a number of ties with the ordinary tie spacing, the effect of the combination of pressures transmitted is readily found by superposing the values of the pressures from the several ties as obtained for a plane at the same depth. For the ordinary width of tie, the effect of the pressure transmitted from the adjacent tie to points midway between ties (overlapping lines of pressure) is noticeable at a depth equal to about half of the usual tie spacing. At a depth of three-fourths of the ordinary tie spacing the pressure immediately under the center of the tie is about one and one-half times that resulting from a uniform distribution over the horizontal plane. At a depth equal to the ordinary tie spacing the lateral distribution has become such that the variation in intensity of pressure from tie to tie is small.

The variation in intensity of pressure in the ballast lengthwise of the tie (which is dependent upon size and stiffness of tie, quality of tamping, and condition of the bed on which the tie rests) becomes

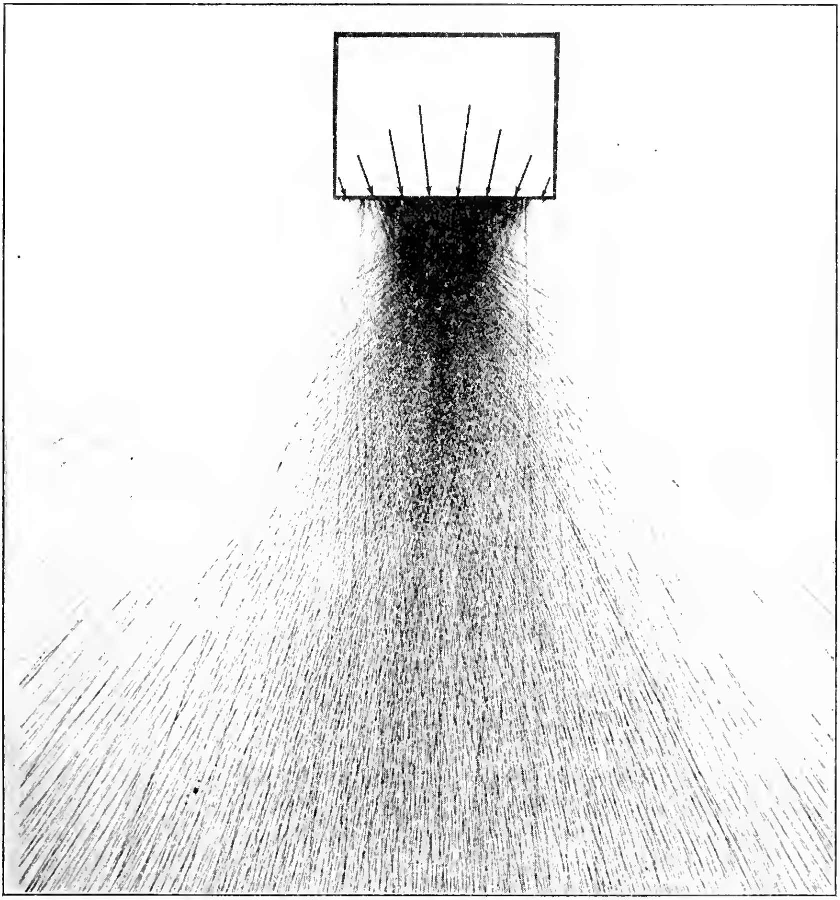


FIG. 100.—DIAGRAMMATIC REPRESENTATION OF LINES OF PRESSURE FOR A TIE 8 IN. WIDE, USING TEN TIMES AS MANY LINES AS ARE GIVEN IN FIG. 99.

less and less with increase in depth, and it may be expected that the variations will be smoothed out at a depth equal to the ordinary tie spacing, or a few inches below, where there will be a fairly uniform pressure over the horizontal plane.

The tests were made on a rigid base and the results may be expected to apply to a firm roadbed capable of carrying the loads transmitted. A depth of ballast greater than that named would be found useful when the roadbed is of uneven character or yields under the load or is subjected to unusually heavy load.

The tests show that for quiescent loading there is little difference in the manner and rate of transmission and distribution of pressure for broken stone, pebble, and sand ballasts; that is, at a given depth the intensities of pressure will be approximately the same, provided of course the ultimate carrying capacity of the ballast is not exceeded, and this conclusion may properly be extended to other non-cohesive materials. It will require less load to force the tie into sand ballast than into broken stone; the ultimate carrying capacity of the broken stone ballast under tie pressure is much greater than that of the sand ballast—the particles of sand ballast are more easily moved and rearrange themselves under lighter loads. For the different kinds of ballast there are great differences in the ultimate load which can be carried on a tie before ballast movement begins. The ultimate carrying capacity depends upon size of particle, smoothness of surface, and degree of angularity. A material whose mobility under pressure is increased by the addition of water or by mixture with other materials may thereby have its carrying capacity decreased. For heavy loading the ultimate carrying capacity of a ballast material is especially important.

It is evident that a principal function of the ballast immediately under the tie and for some distance down, aside from such functions as drainage, is to carry the load without material lateral movement of the ballast to that depth at which lateral distribution becomes effective. An advantage of the coarser, rougher kinds of ballast is that they will carry a greater ultimate load—which is of special importance in the upper part of the ballast. This is especially true under the jarring, vibrating loads of track service for which the ultimate carrying capacity naturally will be less than that found under the quiescent loads used in the tests.

The tests in the laboratory indicate, as would be expected also from analytical considerations, that the presence of ballast above the level of the bottom of the tie may have little influence on the quiescent load which will be carried before the ballast will work out from under the tie and allow it to settle, but that under repeated applications of load and particularly under jarring and vibratory loads the ultimate carry-

ing capacity of the ballast is considerably increased by raising the level of the ballast surface to the top of the tie. This advantage is particularly apparent at the end of the tie, where under the whipping action of the tie under repeated deflections the particles of ballast will more readily be pushed away, since beyond the end of the tie there is no part of the track structure available for resisting the lateral pressure as is the case in the direction of the track, where another tie is always near at hand.

It seems probable that the effect of the jarring action of train loads will be to decrease the lateral distribution of pressure. It seems possible also that this tendency is counteracted in some degree by the cohesion which develops in ballast after it has been in place for some time.

It should be added that the "lines of pressure" used in the discussion are presented as being of service as an illustrative and suggestive conception which will help to explain some of the phenomena of transmission of pressure, rather than as a rigidly scientific hypothesis.

Respectfully submitted,

The Committee to Report on Stresses in Railroad Track

Arthur N. Talbot, *Chairman,*
A. S. Baldwin,
G. H. Bremner,
John Brunner
W. J. Burton,
Charles S. Churchill,
W. C. Cushing,
W. M. Dawley,
Robert W. Hunt,
J. B. Jenkins,
George W. Kittredge,
Paul M. LaBach,
C. G. E. Larsson,
G. J. Ray,
Albert F. Reichmann,
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November 26th, 1919.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

A NOVEL METHOD OF REPAIRING A SWING BRIDGE

By Herbert C. Keith, M. Am. Soc. C. E.

To be Presented April 7th, 1920.

Synopsis.

In the course of the regular inspection of the bridges of The Connecticut Company in 1912, the bottom chords of the swing span of the Washington Bridge over the Housatonic River were found to be in a dangerous condition because of the great loss of section by corrosion, due to the street drainage having been discharged upon the chords for years.

This bridge carries a highway with a single electric railway track, and being on the direct route from New York to Boston, traffic is moderately heavy. There is no other bridge within seven miles to which this traffic could be diverted, and as the Housatonic at this point is a navigable stream, any material interruption to either navigation or highway and railway travel during reconstruction was prohibited.

This paper describes the methods used to renew the chords, with a very material saving of time and money, without impeding traffic. A system of temporary adjustable timber substitute members was devised to carry the bottom chord stresses while the permanent chords were being renewed, allowing the free use of the bridge for half the width

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings,* and, when finally closed, the papers, with discussion in full, will be published in *Transactions.*

of roadway at all times, and also permitting the span to be opened as required for river traffic.

Location.

Washington Bridge, connecting the towns of Stratford and Milford, Conn., crosses the Housatonic River about one mile and one-half above its mouth, and carries the main highway between Bridgeport and New Haven. At this point the electric railway of The Connecticut Company has a single track in the highway, though the line is double-tracked for most of its length.

Original Construction.

The bridge was built in 1893 by Dean and Westbrook for Fairfield and New Haven Counties as a highway bridge, the steel having been fabricated by the Berlin Iron Bridge Company. This structure consists of a 203-ft. swing span with a 232-ft. fixed span at each end. The fixed spans have through pin-connected triangular trusses with curved top chords, each span with eight 29-ft. panels subdivided into sixteen floor panels of 14 ft. 6 in.

The swing span has through pin-connected trusses, Fig. 1, with an 18-ft. rectangular pivot panel flanked at each end by three triangular panels of 30 ft. 10 in., subdivided into six floor panels 15 ft. 5 in. long. The top chord of each arm of this span is curved, with a height varying from 20 to 33 ft. This swing span is entirely center-bearing, but has a turntable with six wheels running on a circular track to provide for unbalanced load. The original bottom chords were 7-in. channels, latticed, 13¾ in. back to back, with splices near the main panel points. In the pivot panel were two additional channels between the outer ones, the latter being continuous with those of the rest of the chord.

In all the spans the trusses are 19 ft. 6 in. on centers, the highway being carried between the trusses by 24-in. plate girder floorbeams hung below the chords by loop hangers passing around the pins and down to tie-plates under the bottom flanges. The plank floor is supported by I-beam and channel stringers resting on cast iron chairs on top of the floorbeams.

One of the designers of this bridge said many years later (after having extensive experience in bridge construction) that he doubted if there was a pound of surplus material in the original bridge in excess of that required to meet the specifications under which it was designed.

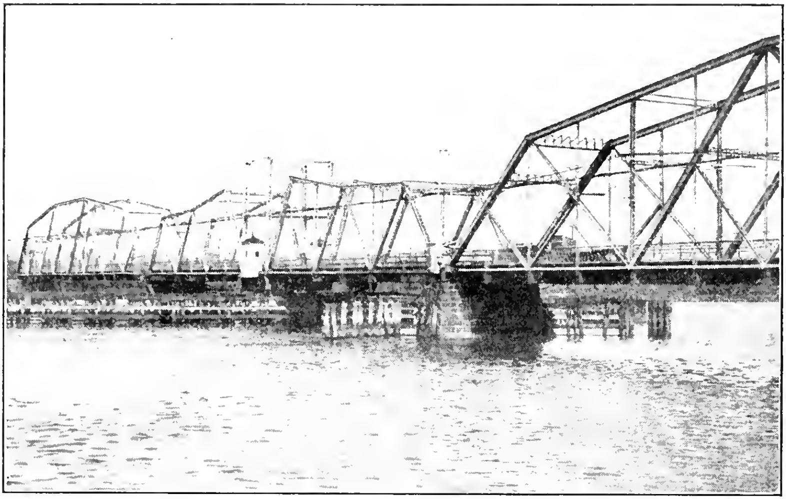


FIG. 1.—GENERAL VIEW OF WASHINGTON BRIDGE OVER HOUSATONIC RIVER.

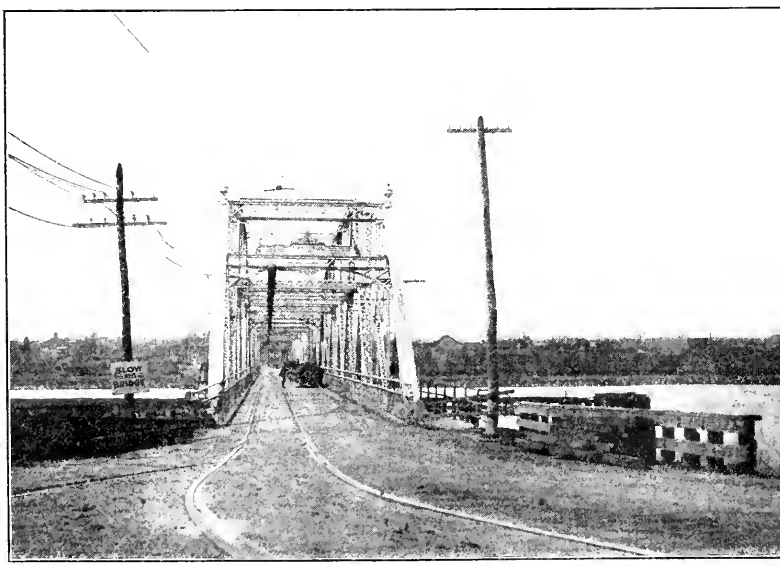


FIG. 2.—EAST PORTAL OF WASHINGTON BRIDGE OVER HOUSATONIC RIVER.

Earlier Repairs and Alterations.

Originally there was no track on the bridge, but one was laid later, its center line in 1913 being 3 ft. 11 in. south of the center line between trusses, as seen in Fig. 2.

The bridge has been strengthened or extensively repaired or altered several times, one of the more recent changes being the addition of a 4-ft. sidewalk on brackets outside of the north trusses. At the same time, The Connecticut Company renewed its track stringers, increasing their capacity, and cover plates were added on both flanges of the floorbeams; additional floorbeam hangers were put on, and some repairs were made to the bottom chords of the main trusses. This work was required not only to provide for increased loads, but because of serious corrosion found on many parts of the bridge.

Condition in 1912.

Examination of this structure in the course of a general inspection of the bridges of The Connecticut Company in the Fall of 1912 revealed the fact that serious corrosion had taken place in the bottom chords of the swing span. Though the bottom chords of the fixed span (being of eyebars) had suffered no material loss, the discharge of drainage from the roadway through slots in the under side of the wheel guards had been very destructive to the latticed channel chords of the trusses of the swing span. The chords of both trusses of this span were in such condition for nearly the whole length that their immediate renewal was necessary, or else the use of the bridge would have to be discontinued. As indicated by Fig. 3, in several places the top or bottom flange of a channel was nearly or entirely gone, and at other places large holes were rusted through the web. Corrosion was general for the whole length of both trusses, but was greatest near the pivot pier, and the inner channels had suffered more than the outer ones.

Some of the pin holes had been enlarged by rust or badly distorted by overstrain (see Fig. 4). Unfortunately no satisfactory photograph was obtained of the worst case of such enlargement, where rust had enlarged the pin-hole more than 1 in. beyond its normal lines.

These facts made it evident that the unit strains upon the reduced chord sections, due to the dead load when the bridge was swinging, far exceeded any possible live load unit strains, and the chief danger of failure was by "breaking its back" when swinging rather than by weakness for carrying traffic.

Factors Affecting the Method of Repair.

The first method of procedure to suggest itself was to construct a temporary bridge with a jack-knife draw on one side of the present bridge, and to divert the traffic thereto. Then the draw of Washington Bridge could be swung open and be blocked up on the fender pier to allow the renewal of the chords. The great expense involved in this method quickly forced the consideration of other possibilities—and quasi-possibilities.

There is no bridge or ferry across the Housatonic River below the Washington Bridge, but the main line of the New York, New Haven & Hartford Railroad has a four-track bridge over the river about $\frac{1}{4}$ mile upstream. The location and construction of this bridge and its approaches, however, are not such as to allow easy or economical diversion of highway or trolley traffic to it. The nearest other public means of conveyance across the river is 7 miles distant; to divert traffic to that route would have added about 12 miles to the 17 miles by direct route from Bridgeport to New Haven.

Both passenger and merchandise traffic across the Washington Bridge is moderately heavy on the electric railway and also on the highway, as the bridge is on the most direct route between Bridgeport and New Haven and between New York and Boston. The inconvenience and expense that would have been caused by the interruption of traffic would have been great. Some of the traffic would have been discontinued or sent by railroad, but most of it would have been diverted to the crossing 7 miles up the river, with an average increased haul of about 12 miles.

The river traffic is lighter, but the Federal Government gives such attention to the maintenance of its water traffic that it is more practicable to stop entirely thousands of travelers on a highway or railway over a navigable stream rather than prevent for a single hour the passage of a yacht, or a tug with a scow, across the line of such highway or railway. It was learned, however, that Nature does each winter what the Government prohibits man from doing—closes the river to navigation for about three months. Records kept for several years show that the ice became so thick as to prevent navigation from December or January to March or April of each winter for which records were available. It was thought that the War Department might be persuaded to allow piles to be driven through the ice, provided that such a

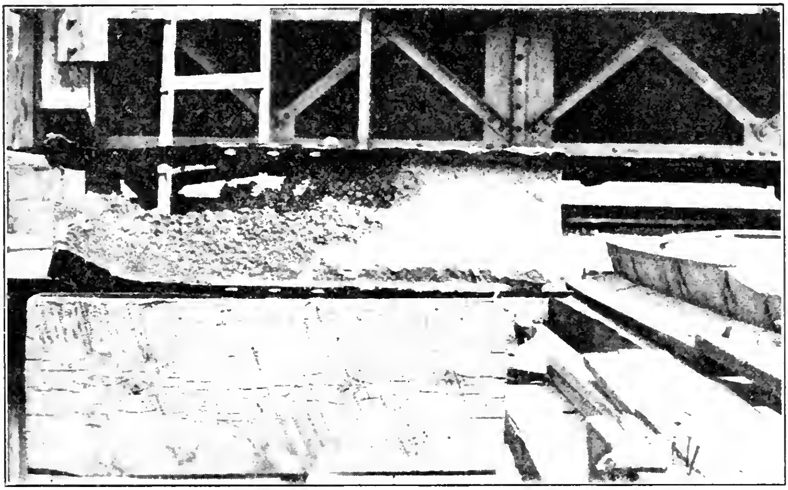


FIG. 3.—INNER CHANNEL OF BOTTOM CHORD OF PIVOT PANEL, SOUTH TRUSS.

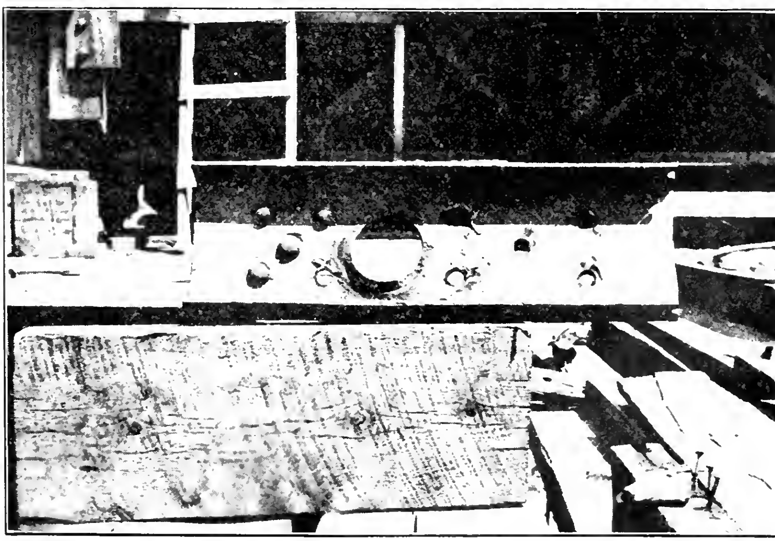


FIG. 4.—INNER CHANNEL OF BOTTOM CHORD OF SOUTH TRUSS AT L_0.

man-built barrier were not allowed to remain to interfere with theoretical open navigation longer than the ice presented its prohibition to actual navigation. However, uncertainty of obtaining such permission, as well as the cost of this method of making the repairs, emphasized the desirability of further study of other methods.

It may be observed from Fig. 5 that though the swing span has six floor panels at each end, yet structurally it has but three panels in each arm, each truss panel having its bottom chord divided into two parts corresponding in length with the floor panels and, of course, having equal stress. As only about a third of the deflection of the draw when swinging was taken up by the end lifts, nearly all the dead load was carried by the trusses to the center bearing even with the bridge closed, very little of this dead load being supported at the ends. This resulted in a constant compressive strain in the whole length of the bottom chords except the end panels, whether the bridge was swinging free or was closed and carrying the maximum live load. Only a small tensile stress was possible even in the end panels. The plans were examined, and careful inspection was made of the structure itself to ascertain whether careless erection or the numerous repairs and strengthenings might have changed conditions from those shown on the plans. It was found that there were small spaces on each of the main pins where jaws of compression members could obtain bearings.

Consideration of these facts led to the adoption of a plan for carrying the bottom chord strains by temporary substitutes while the chords were being renewed, and study of the problem brought conviction that this was not only feasible but a surprisingly economical solution. It avoided the cost of falsework and of constructing a temporary crossing for a detour.

Stress Requirements and Assumptions.

It was assumed that raising the ends of the swing span relieved each truss of that portion of the dead load which was concentrated at the end panel points, L_0, leaving the remaining dead load carried as if the bridge were swinging free. The live load was considered as carried by a continuous truss on three supports. With these assumptions, if— (*a*), the railway traffic were stopped during the progress of the work; (*b*), the sidewalk were removed, and (*c*), the highway traffic were confined at all times to the half-width of the bridge away from the truss on which the work was being done, the maximum stresses in the bottom

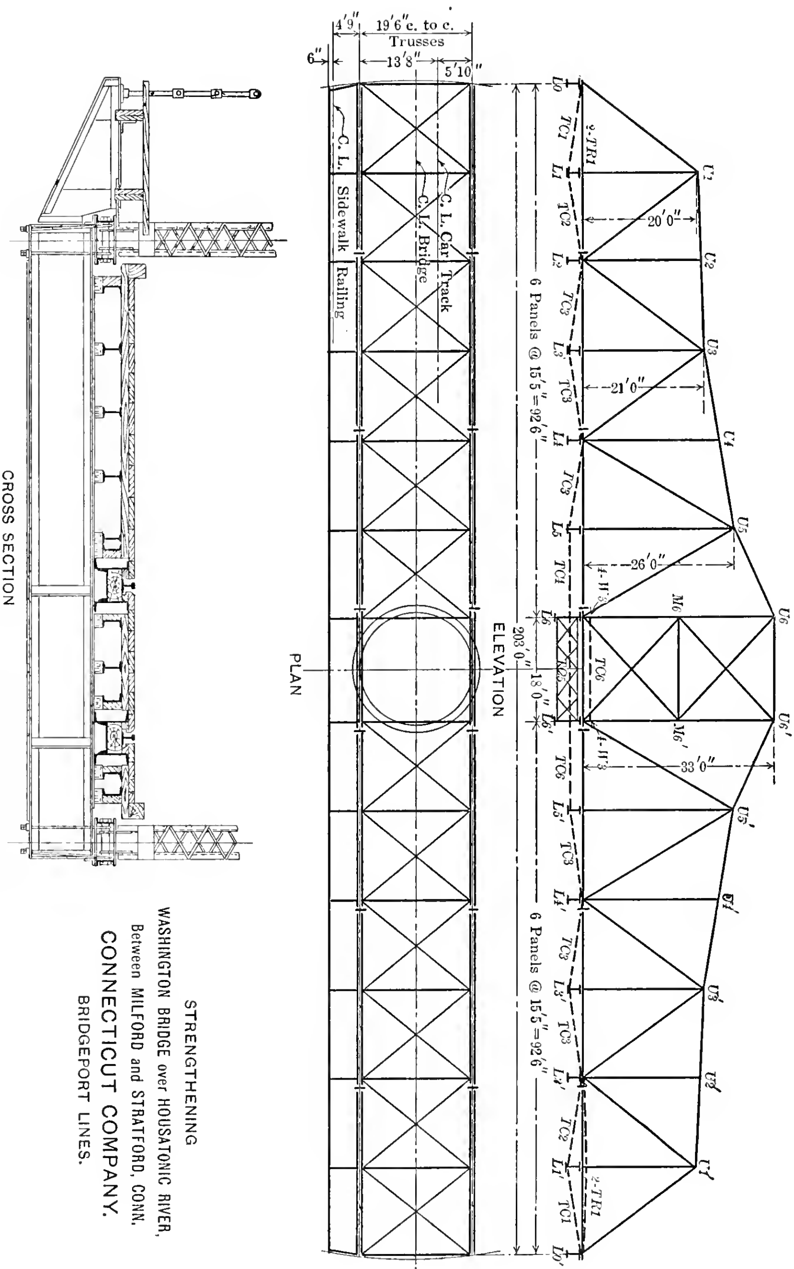


FIG. 5.—ELEVATION, PLAN AND CROSS SECTION, SWING SPAN, WASHINGTON BRIDGE.

chords of the north truss would be: In L_0-L_1-L_2, 6 600 lb. compression or 4 300 lb. tension; in L_2-L_3-L_4, 49 000 lb. compression; in L_4-L_5-L_6, 105 000 lb. compression, and in L_6-L_6' 118 000 lb. compression.

Stresses in the south truss would be slightly less, because there were no sidewalk brackets on the south side.

Outline of Plan Adopted.

Based on the foregoing stresses, a plan was prepared for entirely relieving the steel chord of all compressive strain by the use of a temporary adjustable timber substitute chord (see Fig. 5), each full panel (except as modified near the pivot panel) having inclined struts with jaws bearing against the pins at the main panel points L_0, L_2 and L_4, their other ends abutting against the intermediate floorbeams at L_1, L_3 and L_5, near their bottom flanges.

In the pivot panel, a double timber strut was required, placed horizontally with one timber at each side of the latticed strut, because of the latticed longitudinal strut between the cross girders. These timbers were placed at the level of the lower ends of the timbers in other panels, and the timber in the half-panel at each side of the pivot panel was also placed horizontally and abutted against the cross girder at L_6 directly opposite the double strut of the pivot panel.

As the temporary chord did not bear against the pins L_6 next to the pivot panel, there was left an unbalanced thrust for the batter posts U_5-L_6 in the adjacent panel at each end, which must be transferred across the pivot panel. This was provided for by a timber strut (also adjustable) above the level of the pins, and bearing against the vertical posts U_6-L_6 over the cross girders.

As the chord stress is equal in both parts of a full panel and as the two temporary struts which were used to take the strain abutted against the pins at the main panel points and against opposite sides of the floorbeam at the same height at intermediate points, there was no strain in the floorbeams due to the temporary chord (or substitute), but merely a slight additional tension in the hangers.

In the full panel at each end of the bridge, L_0-L_1-L_2, tension was provided for by two adjustable rods passing over the intermediate pin L_1 and connected by yokes with U-rods around the pins at the main panel points L_0 and L_2. No provision was made for tension in any other part of the chord.

All the weight of the bridge when swinging, and (by the assumption made) nearly all of the dead load and a large part of the live load when the draw is closed, are delivered to the cross-girders at L_6 by the bearing of the bottom chord channels upon the cross-girders, whence it is carried to the center bearing, except for a small amount of unbalanced load carried by the turntable wheels. It is evident that if the chord channels were removed entirely from the top of the cross-girders and no other provision made for supporting the bridge, it would drop until a bearing of the vertical or batter posts was reached on the cross-girders. To prevent such a drop, four wedges $\frac{5}{8}$ in. thick were driven under each pin L_6 just inside the webs of the channels forming the vertical post, and outside of those forming the main diagonal U_5-L_6.

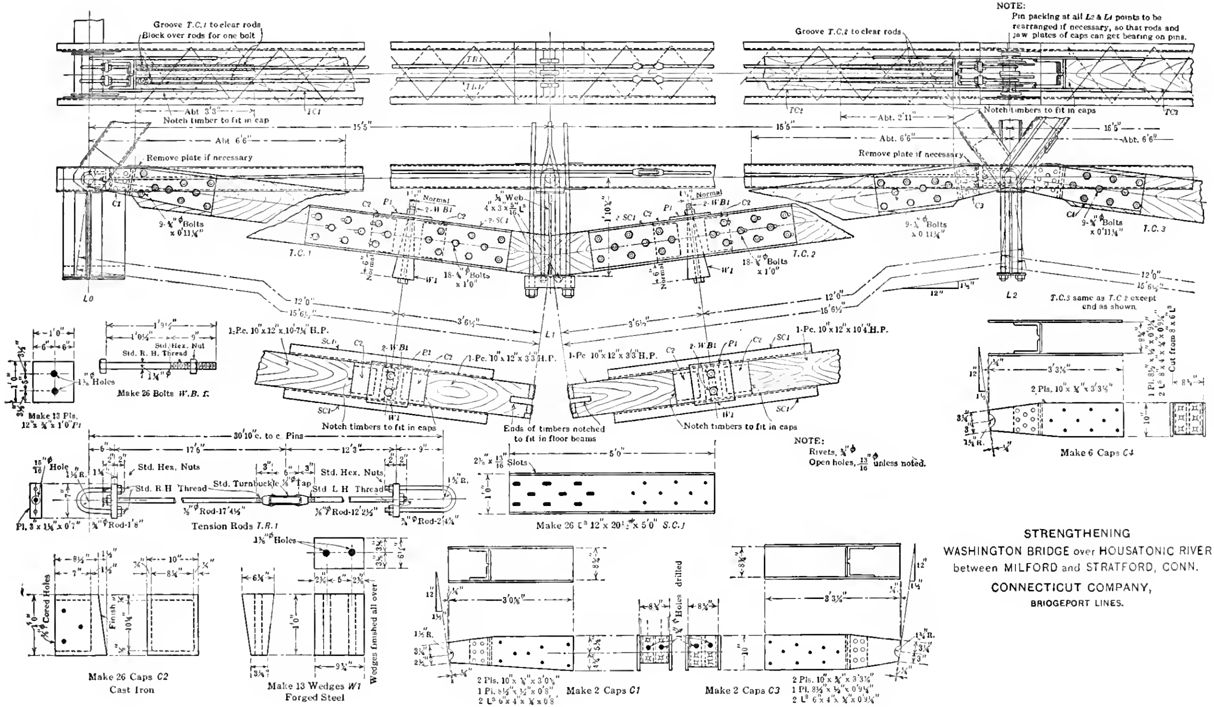
The longitudinal latticed struts between the cross-girders under the trusses were very badly corroded and had to be renewed; and readjustment was required in some of the truss members.

Details of Design.

In the first five sub-panels from each end of the span (see Plate VI) each compression member was composed of two pieces of 10 × 12-in. hard pine timber, separated by a forged steel wedge sliding vertically between cast iron caps on the timbers, thus allowing for adjustment in the length of the member.

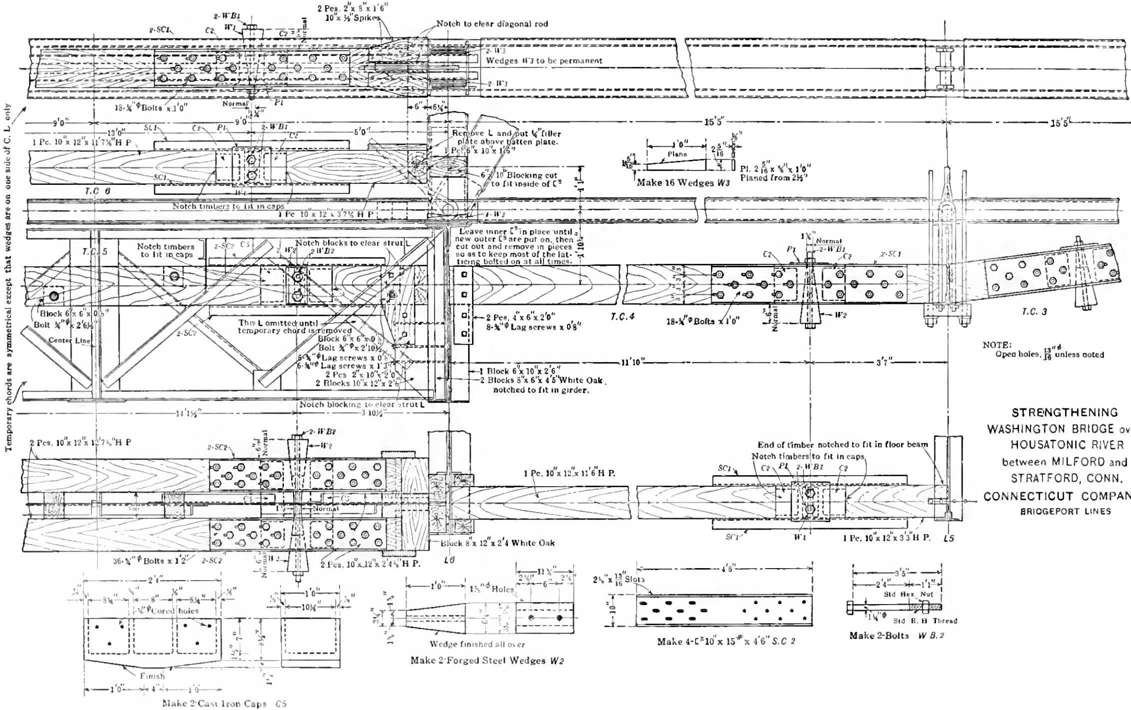
The lower end of this strut was trimmed so that it would bear solidly against the web and bottom flange of the intermediate floorbeam, while the upper end was cut down to a width of $8\frac{3}{4}$ in., and sawed off square to butt against the diaphragm of a steel cap with $\frac{3}{4}$-in. jaw-plates bolted one on each side of the timber. These jaws projected beyond the end of the timber and diaphragm, and had their ends cut out semi-circularly to fit against the main truss pin. Between these jaw-plates, and bearing against the end of the timber, a $\frac{1}{2}$-in. diaphragm plate was attached to the jaws by two angles 8 (or 6) × 4 × $\frac{3}{4}$ in., the rivets being countersunk in the diaphragm so as to present a flat surface for bearing on the end of the timber.

The wedge was located $3\frac{1}{2}$ ft. from the floorbeam end of the strut, and had two planed surfaces, each with a slope of 1 in 8, sliding between planed surfaces of the cast iron caps on the timbers. Two $1\frac{1}{4}$-in. bolts, passing through the wedge and through a washer plate 12 in. square



STRENGTHENING
WASHINGTON BRIDGE over HOUSATONIC RIVER
between MILFORD and STRATFORD, CONN.
CONNECTICUT COMPANY,
BRIDGEPORT LINES.

PLATE VII.
PAPERS, AM. SOC. C. E.
FEBRUARY, 1920.
KEITH ON
A NOVEL METHOD OF REPAIRING A
SWING BRIDGE.



STRENGTHENING
WASHINGTON BRIDGE over
HOUSATONIC RIVER
between MILFORD and
STRATFORD, CONN.
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BRIDGEPORT LINES

by $\frac{3}{4}$ in. thick, were used to draw the wedge into place and to prevent its slipping. Two scabs of 12-in. channels 5 ft. long were bolted to the strut, one on each side, to maintain the strut in proper line. These scabs were secured to the component timbers by nine $\frac{3}{4}$-in. bolts for each timber, three of which passed also through the cast iron cap. The holes in the scab channels for the bolts for the lower, and shorter, timber were $\frac{13}{16}$ in. in diameter, while those for the bolts for the other timber were slotted to $2\frac{3}{8}$ in. in length. These bolts were left loose until the wedges were drawn up the full amount, and then tightened. The slopes of 1 in 8 (or $1\frac{1}{2}$ in. per foot) were adopted for the wedge as nearly balancing the friction, if the faces of the wedge were well greased the coefficient of friction being estimated at about 0.15.

Later experience confirmed this estimate, for when the bolts were slacked off it required the tap of a hammer (in some cases a hard blow) to loosen the wedges.

In the half-panel next to the pivot panel (Plate VII), the strut was made similar to those in the first five half-panels except that instead of the jaw connection for the pin at L_6 the strut was placed horizontally with a square end of the timber abutting against the web of the cross-girder under the pin L_6. Blocking underneath and at both sides of the strut held it securely in place.

In the pivot panel a double strut was used: it was laid horizontally and level with those in the adjacent half-panels, but with one line of timbers on each side of the permanent latticed steel strut between the cross-girders, which (except one diagonal temporarily omitted) had been previously renewed. These timbers were bolted together through spacing blocks at three points, and had double cast iron caps for wedges sliding horizontally, the two wedges being drawn in by two $1\frac{1}{4}$-in. rods passing through both wedges. At the expansion joints 10-in. scab channels, similar to the 12-in. channels in the other panels, were used, but they were placed on top of and underneath the timbers. Blocking held the struts in place at points of bearing against the cross-girders and to distribute the pressure of the two struts of this panel so as to oppose the single struts of the adjacent half-panels without straining the webs of the cross-girders.

A strut was placed 13 in. (on centers) above the chord in the pivot panel to take the unbalanced thrust of the diagonal posts of the adjacent panels. Its construction was similar to that of the other

timber struts, and its ends butted against blocking on the channels of the vertical truss posts, blocking also being placed within the post to stiffen it locally.

In the full-panel at each end of the span (Plate VI) the temporary $\frac{7}{8}$-in. rods were provided with turnbuckles for greater convenience, although adjustment was possible at the yokes where the main rods were connected with the U-bolts passing around the pins.

SPECIFICATIONS.

As is frequent in the author's practice in the design and construction of such bridges or their repair, the specifications prepared by Professor George F. Swain, Past President of the Society, and issued by the Massachusetts Railroad Commission, were adopted as the basic specifications for this work. As the proposed method of conducting the reconstruction required great care in its execution, or it would result in disaster instead of an improvement, supplementary specifications were prepared going into more than usual detail as to the methods to be used, precautions to be taken, and the order in which the work should be performed.

It was provided that the electric railway traffic should be suspended across the swing span during the progress of the repairs, and that other traffic should be restricted at all times to the half-width of roadway away from the truss upon which work was being done at the time. In preparation for renewing the chord of the north truss the sidewalk was to be removed and stored properly so that it might be replaced after the chord had been renewed.

The strengthening of one truss was required to be completed before work should begin on the other; and for each side of the bridge it was prescribed that the work should proceed in the following order:

The new longitudinal strut in the pivot panel under the truss between the cross-girders, should be placed and entirely riveted, except as noted, before any work is done upon the truss itself.

Obstructions to placing the temporary chords, such as tieplates and lattice bars, might be removed when necessary, but in such case temporary blocking and clamps should be placed in order to properly stiffen the chord channels.

All the temporary material for one truss was to be put in place and the slack taken up (but without strain), and examination was to be

made of each member to see if the anticipated additional wedging would leave the wedges within the prescribed limits of position, before the wedging should be begun which was to relieve the main chords. The driving of these wedges was to begin at the pivot panel and proceed thence toward the ends, keeping the conditions approximately equal in the corresponding panels of the two arms. Wedges were to be well lubricated, and when fully drawn into the position which should remove all the strain from the main chords they should bear for at least three-quarters of their length upon the caps. All the bolts in the scab channels for the temporary struts were to be put in place and the nuts placed on the ends of the bolts, but left loose until the wedges were in their final positions. After the wedges were adjusted so that no strain whatever was left in the main chords the nuts must be tightened before any chord section could be removed.

It was specified that the entire temporary chord, including the adjustable rods of the end panels, should be in place and satisfactorily adjusted so that the main chord should be entirely free from strain, and the bolts through the scab channels tightened up, before any section of chord channel might be removed. The renewal of the chord channels should begin at the ends and proceed toward the pivot panel, only one section of chord channel being off at once, the lacing and tie-plates being bolted on as soon as practicable. Where the temporary work prevented immediate replacement of tieplates and lacing, blocking and clamps should be used to stiffen the new chord channels the same as specified for use with the old ones before renewal.

Wedges on the cross-girders under the pins L_6 were specified to be driven before the old chord was removed, and to be withdrawn after the new chord sections should be in place; after which they were to be redriven to a firm bearing and secured in such a manner as to prevent their working out. At the time of writing the specifications it was not realized that the pinholes in the chord channels had been so deformed by rust and overstrain that a settlement of from $\frac{1}{8}$ to $\frac{5}{16}$ in. had occurred at these points, requiring a corresponding lift of the whole bridge in order to allow the new chord channels to be put on.

The experience in driving the wedges the first time led to the cancellation of the requirement for their withdrawal and redriving. It was specified that short pieces of the inside channels at L_6 (there being

four channels in each chord section in the pivot panel) should be left in place to help deliver the weight of the bridge to the cross-girders.

PRECAUTIONS TAKEN TO INSURE SAFETY.

From the inception of this method of renewing the truss chords it was fully appreciated that any carelessness, either in design or execution of the work, would be fraught with danger; so special precautions were taken to insure its success. Consideration was given to the matter of economy, but when the question was the choice between low cost attended by danger and a somewhat higher cost coupled with safety for life and material, there was no hesitation in choosing safety. In its basic principles the method proposed was so decidedly economical that there was less incentive to reduce the cost by the last cent possible, or to use too delicate scales in balancing safety against cost.

Extensive experience in the conduct of repair work brought a realization that, even more than in new work, carefully prepared specifications and plans were not by any means a guaranty that the actual work would be done as indicated by them. Therefore, when the plans were presented it was stipulated that, if they were adopted, the work must be done under careful engineering supervision by a contractor, foreman and crew who had been found dependable on other similar undertakings.

It was recommended, also, that payment for the work should be put on such a basis that undue desire for profit should not lead the contractor into careless methods. Arrangements were made to give the author absolute jurisdiction, and that he should be represented at all times upon the work by a trusted assistant as resident engineer; also, that he should be present in person during the more critical stages of the work. A contractor and foreman who had aided the author and his staff many times in seeking "safety first" on other critical work, and had inspired complete confidence, were chosen to do the work, which was carried on under a "force account" contract.

In many cases the stresses to be provided for would have permitted the use of smaller timbers, and correspondingly smaller wedges, caps, etc., for the temporary work, especially if it could be assured that they would be subjected to no other strain than that of direct compression parallel with the axis of the timber. Practical consideration of all the demands that might be made upon them, however, prompted the use

of 10 $\times$ 12-in. timbers throughout, and wedge and channel reinforcement of a uniform type, so far as practicable.

As a further precaution, extra timbers, wedge, caps, and bolts were provided for use in an emergency, and timbers and blocking were made available so that in case of difficulty in drawing up the wedges the bridge could be swung open and blocked up on the fender pier. Except two wedge bolts these extra supplies were not required, and after the completion of the work the timbers were returned to the lumber company without other expense than the mere hauling to and from the bridge.

Though it was considered safe to swing the draw at any time during the progress of the work, it was thought desirable as an additional precaution to avoid such turning if practicable. Preparation was therefore made to execute the work during the season in which navigation would be closed by ice. It is evident that the author can lay no claim to being righteous, for "the good book" states that the "fervent prayer of a righteous man availeth much." Certainly his prayer for a long closed season was fervent; but the winter of 1912-13 proved to be a very unusual one, and the longed for ice came in such moderation that navigation continued without interruption. Nevertheless the work went ahead and was completed with no mishap whatever.

Construction Work.

All materials for the work, both for temporary use and for permanent construction, were made ready and collected on or near the bridge before work was commenced on the existing structure. A barricade was erected at the end of each approach span just outside of the permanent gate, and a fence was built for the whole length of the swing span to confine the traffic to the south side of the draw, leaving a little more than half the width of the roadway clear, and protecting the men at work on the north truss. The sidewalk floor outside the north truss was taken up, and the north tender's house (used only for storage of supplies) was removed except the roof, which was hung by slings from above because of the counter rods of the truss passing through it.

The first work, except that of preparation, was the removal of the longitudinal struts between the cross-girders of the turntable and their replacement with new material. This was completed and riveted (except one diagonal omitted for the time being to allow the wedge cap of the temporary chord to pass through the strut) before any work was done on the truss chord itself.

The temporary chord (or temporary substitute for the chord) was then put in place, but without strain, for the whole length of the north truss. Each sub-panel strut was handled in two lengths, the long timber with its wedge-cap and the jaws for the pin comprising one part, and the short timber and its wedge-cap with the channel scabs bolted on loosely forming the other. These two lengths were put together in place, the bolts put through the scab channels and the long timber, and the nuts caught on the bolts but not turned up (see Fig. 6).

This held the strut (minus the wedge) sufficiently in position to release the men and the tackle for the heavier work of hoisting the wedge into place, after which the bolts and washer plates were added and the wedge was drawn up just enough to take up the slack. The lengths were made such that this condition left the wedge bearing for about half of its length on about half of the depth of the strut as shown by Fig. 7.

In the pivot panel the double strut was placed in a similar way, with one line of timbers inside and one outside (see Fig. 8) of the permanent strut between the cross-girders, except that the wedge-caps (being double caps serving both struts and passing through the permanent strut where the diagonal was omitted temporarily) were placed separately from the timbers. Consequently the scab-channels were also handled separately. This was done the more readily here because these timbers could be hung upon the permanent strut. In this panel the channel scabs were on the top and bottom of the timbers, and the wedges were drawn horizontally from the inside and outside, a single pair of rods serving for both wedges.

Before placing the upper temporary strut of the pivot panel the $\frac{5}{8}$-in. wedges W_3 were driven under the main truss pins between the pins L_6 and the cross-girders (or bearing-girders). As these pin-holes had been enlarged by rust and overstrain, there had been such a settlement as to require a lift ranging from $\frac{1}{8}$ to $\frac{5}{16}$ in. The cramped space for these wedges added to the difficulty of driving them into place, but this was accomplished satisfactorily. Afterward, the upper temporary strut was placed between the truss verticals. The wedges under these pins were left in place, not being withdrawn temporarily as specified: It was not found necessary to pin them to prevent their working out. Blocking was used inside the posts, and between the strut timbers and the posts, to distribute the strain and stiffen up the post channels. In

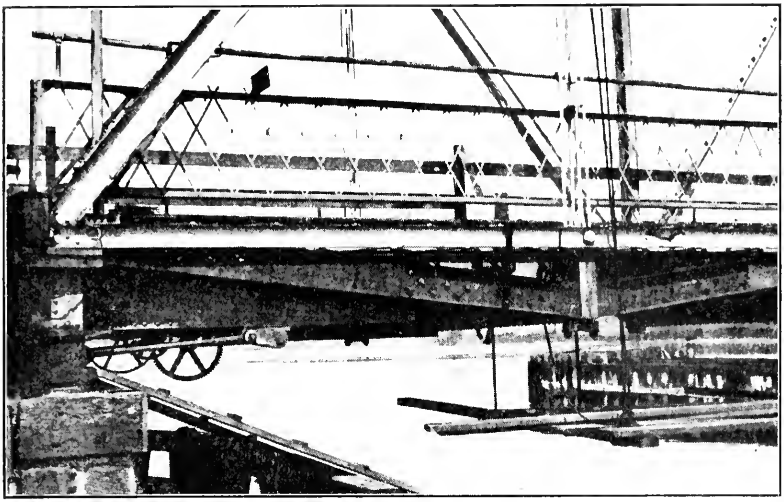

Fig. 6.—Temporary Chord in Place at West End of South Truss.

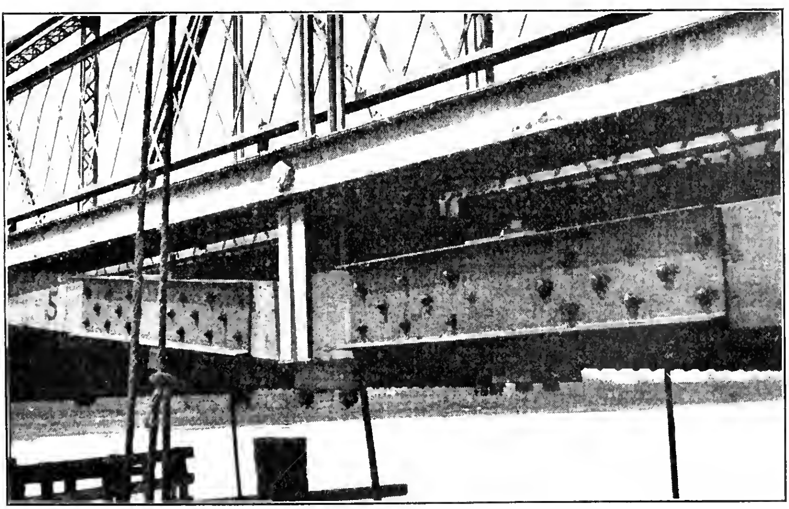

Fig. 7.—Temporary Bottom Chord $L_4L_5L_6$ in South Truss.

this temporary strut the scab-channels were placed on the upper and lower sides of the strut, and the wedge was driven horizontally.

Temporary tension rods TR_1 in the end panels (see Plate VI) were placed by first inserting the long rods through the lacing of the chord and passing their ends through the pin-caps of the temporary struts. Yokes were then put on the ends of the rods and the nuts turned up, the loop ends put around the pins and through the yokes, and the turnbuckles added and turned up sufficiently to take up the slack.

In placing the temporary struts or rods it frequently became necessary to cut away the tieplates and lacing bars, but whenever this was done suitable blocking and clamps were put on to stiffen the chord channels properly (see Fig. 9). This was done also to stiffen the channels of the new chords before the temporary struts were removed, so that the tieplates and lacing could be bolted on. At some pins a slight readjustment of the pin-packing was required to allow the proper insertion of the jaws of the temporary struts.

When the temporary work for the renewal of the chord of the north truss was in place for the whole length of the swing span, with the slack taken up but without taking any strain, all parts were examined carefully to see if any refitting was required. Everything being found satisfactory, the work of drawing in the wedges was begun, starting at the pivot panel and working toward the ends, keeping the advance approximately even in the two arms. At each wedge the nuts were turned up a little on the rods alternately, using a long-handled wrench with the handle lengthened by the addition of a piece of pipe so that three men could work together on the wrench while a fourth assisted by striking the head of the wedge frequent blows with a sledge. The chord was considerably relieved of strain in the pivot panel, L_6-L_6' (see Fig. 5), and the adjacent panels L_4-L_5-L_6 toward each end before any wedging was done in more distant panels. The middle panels L_2-L_3-L_4 of each arm were then wedged until there was hardly any strain left in the truss chord. The men returned to the pivot panel and those next to it on each end, and the strain was entirely taken out of the chord. After this, the remaining strain in the middle panels was removed, and the end panels, L_0-L_1-L_2, were relieved of all possibility of strain, whether the ends of the span were lifted or were swinging free, by wedging the compression struts and by tightening up the turnbuckles on the tension rods.

As had been expected, a slight strain was now found in the chord of the pivot panel and those adjacent to it, although previously entirely free from strain. Accordingly the wedges in these panels were drawn in a little more to relieve the chord again entirely. Then each section of channel for the whole of the span was sounded carefully to make sure that it was absolutely "dead", and every nut on the wedge rods and each tension rod in the end panels was tested in order to be sure that the rods of each couple were dividing the stress about equally.

When everything was found to be in proper condition, the nuts were turned up tight on the bolts through the channel scabs, and the work was left for the night with a feeling of satisfaction. All pin-nuts for this truss were loosened so as to be removed easily and quickly (in most cases by hand) when required, but left on the pins, and so close to the chord channels that no channel could slip off the shoulder of the pin before its removal was desired. Several pin-nuts were broken in their removal, but a supply had been provided for this contingency. As more new nuts were required for the north truss than had been anticipated, an additional reserve was obtained in order that there should be no lack later.

The first work the next morning was to retest carefully all details to see if any change had taken place during the night. Everything being satisfactory, the lacing and tie-plates were removed from the outer channel of the first panel, L_0-L_1-L_2, at the east end, and this channel taken off. The test of the plan of renewal was not to be delayed greatly; for hardly had this channel been removed when a whistle was heard calling for the opening of the draw. There was no time for substituting a new channel, so the work was stopped, all staging connecting the moving with the fixed structure was shifted to be carried entirely by the one or the other, and orders were given to open.

During the whole time the bridge was open the engineers and the foreman carefully observed the temporary structure, sounding the steel chord channels to see that they received no strain because of the movement. The result of this observation was so reassuring that thereafter no hesitation whatever was felt about opening the bridge as often as desired; in fact, after the draw had been swung a few times the work went on while the bridge was open just about the same as when it was closed, except for the removal of planks and ropes connecting it with the piers and fixed spans. Several times some of the workmen did

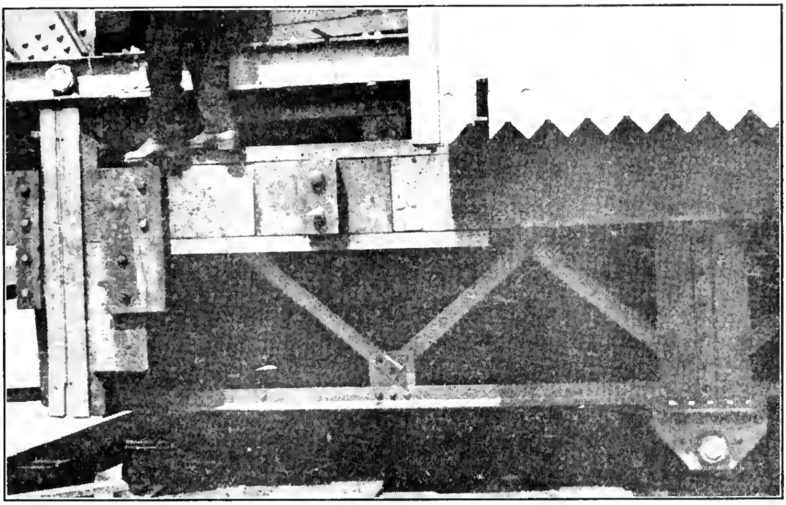

Fig. 8.—Temporary Bottom Chord in Pivot Panel of South Truss.

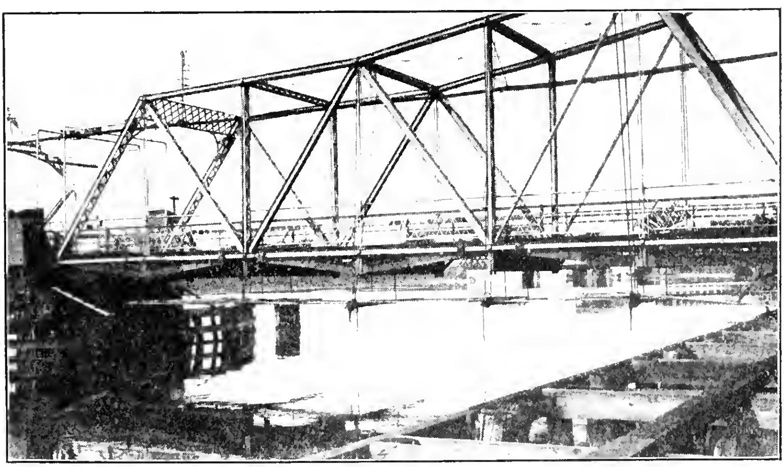

Fig. 9.—West Half of South Truss with Temporary Chord in Place.

not even notice that the bridge had moved until they heard the noise of the machinery lifting the ends after the bridge was closed.

When the draw was closed again the new outer chord channel was put in place, and the hanger for the end floorbeam bolted to it. Then the inner channel was removed and a new one substituted. When both new channels of this section of the chord were in position and the nuts replaced on the truss pins, as many of the tieplates and lacing bars as practicable were bolted on, and such blocking and clamps added as were necessary properly to stiffen that portion of the length which was left disconnected. Bolts were put in the gussets connecting the chord with the end floorbeam; the latter bolts were replaced by rivets as soon as practicable, but those in the tieplates and lacing were allowed to await a more convenient time.

The renewal of the second and third panels followed rapidly, completing the east arm of this truss except for a short space near the pin L_6. In like manner the lower chord of the west arm of this north truss was renewed for an equal length; after which the new outside channels of the pivot panel were placed and the inside channels of this panel were cut off a few inches from the pin. As required by the specifications, a short piece of each of these inside channels was left in place to assist in delivering the load of the truss from the pin to the cross-girder.

As fast as sections of chord were added, the splice plates were bolted tight with bolts in about half of the holes and drift pins in the other half. Riveting of the splices was done as soon as convenient after the temporary work was removed, but riveting of the tieplates and lacing, as well as the replacing of the sidewalk, was allowed to await the convenience of the work.

When the whole chord was in place and the splices bolted, all anxiety about the success of the plan was over, but some difficulty was experienced in the removal of the wedges. As their slopes were slightly less than the angle of friction of the bearing surfaces after the lubricant had been squeezed and dried out, some coaxing was required in starting them. In fact, in some cases it proved harder to force them out than it had been to draw them into place. It was considered unsafe to remove both bolts entirely from a wedge, because a sudden movement of the wedge might endanger the chords by the impact as well as cause the loss of the wedge. The bolts were slackened a little and the wedge

"teased" along by blows of a hammer against the side of the broad end, where it extended beyond the under side of the strut. In the worst cases, one of the bolts was slackened off and the other removed entirely, allowing a bar to be put through the hole in the washer plate and the wedge to be driven out by blows against the thin end of the wedge.

Work on the south truss was similar to that on the north truss with two important exceptions, viz.—all the men were experienced in their respective duties, and the inconvenience of the sidewalk brackets, etc., was absent; progress therefor was more rapid. In one respect, however, work on the south truss was more difficult, because there was greater distortion and corrosion of the pinholes at L_6 over the cross-girders. This caused the most troublesome operation on the whole work, as it added to the difficulty of raising the truss to its original position. The identical material was used for temporary work for the south truss that had been used for the north, except that two new bolts were required for drawing in the wedges, to replace those with worn threads.

After the new chords were in position, riveting and some adjustments of floorbeam hangers completed the work of restoring the bridge to a capacity considerably greater than before corrosion and distortion had injured it.

Conclusion.

In comparison with what would have been required had the repairs been made by providing for a detour, so that the draw span might be blocked up on the fender pier for the renewal of the chords, the money cost and the interference with traffic by this method of reconstruction were remarkably small.

The total cost of the work, exclusive of engineering expense and that of watchmen, was \$5 900. Vehicular traffic was confined to the half-width of bridge for about six weeks; trolley passengers were obliged to transfer, with a walk of about 300 ft., for a similar period of time. Shipping suffered no obstruction whatever, for the bridge was swung as freely as usual.

Although no definite estimate was made of the cost of a detour, with a temporary viaduct and jack-knife draw, it is believed that this cost, with provision for car service, would have been at least \$100,000. This plan would have saved the transfer of trolley passengers, but all

traffic would have had 300 ft. increased length of haul (about equal to the distance that traffic was restricted by the adopted plan), and an undesirable grade at each end of the detour would have been introduced. As a temporary draw is slow of action, the interruption to traffic probably would have been as great as it was with the short gauntlet required by the plan described in this paper.

Interference with navigation surely would have been greater with a temporary trestle and jack-knife draw, unless there was justification for the suspicion several times expressed when a tug passed up the river a short distance, and returned soon without any apparent reason for the trip. It was intimated that these trips might have been taken in the hope of a refusal to open the draw, in order to obtain a basis for a damage claim. No cause for such claim was given, however. The time required for the work would have been much greater with such a detour than was the case by the method adopted.

The cost of a detour might have been reduced somewhat by omitting provision for the use of cars on the temporary bridge, but even with this saving it would have involved many times the cost of the method adopted. Such an omission would have required a transfer of trolley passengers and necessitated their walking about $\frac{1}{4}$ mile.

Although the success of the method was never doubted by the author, he realized that some individual might be criminally careless and neglect his plain duty, or that the seriousness of some otherwise minor accident might have been increased because of the reconstruction work. There was therefor a feeling of relief when the work was safely completed, also intensified by the fact that an eminent engineer had expressed a fear that "the bridge would be dropped into the river before the task was finished".

Hearty appreciation is felt for the constant interest shown by James L. Parker, the author's principal assistant, and Guy Pinner, his detail designer and resident engineer during construction, Assoc. Members Am. Soc. C. E., for their careful study of the problems involved; also to the United Construction Company, the contractor, and to Charles Sones, their faithful and careful foreman, and to each of his men for their helpful attitude, so necessary for the successful prosecution of the work without the slightest accident.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

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ON A NEW PRINCIPLE IN THE THEORY OF STRUCTURES

Discussion*

By William Cain.

William Cain,† M. Am. Soc. C. E. (by letter).‡—Prof. Swain published in the *Journal* of the Franklin Institute, for February, March, and April, 1883, a paper "On the Application of the Principle of Virtual Velocities to the Determination of the Deflection and Stresses of Frames", the method being based principally upon the investigations of Mohr and Winkler. It is interesting to note that the author has taken up the subject again after 36 years, and has applied the method to finding the rotation of a section of a beam or truss, under given loading; eventually applying the results to deducing the "Theorem of Three Moments" and in making other interesting applications. The formulas and their applications are sound in theory and are neatly and concisely presented. Mr. Cain.

It is true, as pointed out by both Prof. Church and Mr. Mensch, that Equation (6) is implicitly contained in a theorem of Castigliano,§ but the author deserves our thanks for putting it in this definite, explicit form, where no differentiation is called for. The method of the author does not require, as in the "moment area" method, that the beam or frame should be fixed in direction anywhere, but it does require immovable abutments, and that the reactions at the abutments,

* Discussion of the paper by George F. Swain, Past-President, Am. Soc. C. E., continued from October-November-December, 1919, *Proceedings*.

† Chapel Hill, N. C.

‡ Received by the Secretary, January 21st, 1920.

§ The writer first had the pleasure of introducing Castigliano's masterly treatise on "Systèmes Elastiques" to the notice of American engineers in a paper, published in *Transactions*, Am. Soc. C. E., Vol. XXIV, p. 265, April, 1891. In this paper, some original demonstrations of the method of deflection and least work were given, besides a general resumé of Castigliano's fundamental theories and methods, with some applications.

Mr. Cain. whether due to the loads alone, or to the fictitious couple, should all be included in the forces acting on the structure, which is then taken as a free body, in equilibrium under the loads and reactions, including any restraining couples acting at the abutments.

When these conditions are observed, the author's Equation (6) gives the rotation of a section of a beam or truss when the summation (or integration) covers the whole beam or all the members of the truss. Thus, for the simple beam, Fig. 2, subjected to a load P and a couple, whose moment is $M = 1$, applied at the right end, the beam is free under these loads with their corresponding reactions. Then, when the integration covers the entire span, Equation (5) gives the rotation (in radians) of a vertical section where the couple is applied. It would be erroneous to apply the method to only a part of the truss, for reasons given later.

By Castigliano's method, where an actual force at the point, acting in the required direction, (or an actual couple at the desired section), is not available, an arbitrary force (or couple) is applied at the point (or section), which is eventually taken equal to zero; then, the partial derivative of the internal work of the structure with respect to the force gives the deflection, at that point, in the direction of the force, and the partial derivative of the internal work with respect to the moment of the couple, supposed applied at a section, will give the rotation of that section.

Thus, in the case of arches subjected to vertical or inclined loads, there are introduced at a point on the axis a horizontal force w, a vertical force w', and a couple of moment m: then, if L is the internal work of the arch, expressed in terms of w, w', and m and the given loads, then, taking partial derivatives and, in the end, making w, w', and m equal to zero,

$$\frac{dL}{d\,w} = \text{horizontal deflection of point;}$$

$$\frac{dL}{d\,w'} = \text{vertical deflection of point;}$$

$$\frac{dL}{d\,m} = \text{rotation of section at point,}$$

all for the actual loads only.

In the case of a long column subjected to an inclined load at the top, eccentrically applied, the general solution is effected with the use of only the two loads w and w'. In other cases, only one load or one couple may be used. To give an illustration of Castigliano's method, take the case of the simple beam, shown in the author's Fig. 3, where a load P is applied at a distance a from the left abutment and an arbitrary couple, which is taken left-handed, is supposed applied to the beam at the load, say by means of a bar bolted to the beam. If

Mr. Cain.

M_1 is the moment of the couple applied at P, its left reaction acts up and equals $\frac{M_1}{l}$, and its right reaction acts down and also equals $\frac{M_1}{l}$.

Call M the moment of all forces from the left abutment to a section x ft. from the left abutment, or x_1 ft. from the right abutment.

$$o < x < a, M = P \frac{l-a}{l} x + M_1 \frac{x}{l}; \therefore \frac{d\,M}{d\,M_1} = \frac{x}{l}$$

$$o < x_1 < (l-a), M = P \frac{a\,x_1}{l} - M_1 \frac{x_1}{l}; \therefore \frac{d\,M}{d\,M_1} = -\frac{x_1}{l}.$$

Now, neglecting shear, the internal work for the beam is given by the well known formula

$$L = \frac{1}{2} \int_0^l \frac{M^2}{E\,I}\,dx$$

whence the rotation of a vertical section at the load is

$$\alpha_1 = \frac{d\,L}{d\,M_1} = \int_0^l \frac{M}{E\,I} \frac{d\,M}{d\,M_1}\,dx.$$

On putting $M_1 = 0$ in the values of M given above and then substituting the values of M and $\frac{d\,M}{d\,M_1}$ pertaining to the parts of the beam to the left and right of the load and integrating between the limits $x = 0$ and $x = a$ for the left part, and between $x_1 = 0$ and $x_1 = (l-a)$ for the right part, we are conducted to the integral given by the author, and thus to his value

$$\alpha_1 = \frac{P\,a\,(l-a)\,(2\,a-l)}{3\,E\,I\,l}.$$

As this is negative, the rotation of a vertical section at the load is in the opposite direction to that of the couple, or clockwise. Since the influence of shear on bending was neglected, this value of α_1 likewise gives the slope of the elastic curve (in radians) at the load, which is thus downward to the right.

It is seen that the values of $\frac{d\,M}{d\,M_1}$ above are the same for any value of M_1 and therefore for $M_1 = 1$, in which case the moments due to this couple of moment 1 are exactly the values given by the author, so that $\frac{d\,M}{d\,M_1} = M_r$ as defined by the author. In fact, this is generally true for all cases, since M is always a linear function of M_1 for any structure, hence the author's Equation (5) is identical with Castigliano's formula

$$\alpha = \int \frac{M}{E\,I} \frac{d\,M}{d\,M_1}\,dx$$

for any beam, straight or curved.

Mr. Cain. As to the more general formulas for Δ and α, Prof. Church, in his discussion, has so thoroughly pointed out the equivalence of the author's and Castigliano's formulas, that it seems superfluous to make any further comment thereon.

Where an external couple acts at the required section, it is not necessary to add the arbitrary couple. Thus, for the beam supported at the ends and subjected only to a couple M_2 at the right end, Fig. 6, we have

$$M = \frac{M_2}{l} x; \quad \therefore \frac{d\,M}{d\,M_2} = \frac{x}{l}$$

and the rotation of a vertical section at the right end is

$$\alpha = \int_0^l \frac{M}{E\,I} \; \frac{d\,M}{d\,M_2} \, dx = \frac{1}{E\,I} \int_0^l \frac{M_2\,x^2}{l^2} = \frac{M_2\,l}{3\,E\,I}.$$

Since α is positive, the rotation is in the direction of that of the couple, or counterclockwise. The same final result would be obtained by the use of an arbitrary couple at the right end, but the work is slightly greater.

Mr. Mensch, in his comprehensive discussion, premises that the theory, in its most general form, is based upon the law that

$$\text{external work} = \text{internal work};$$

where "external work" includes that of the loads and reactions (including restraining couples, if any). It is thus evident that the usual formulas are only true for immovable abutments, where the reactions do no work.

It may be well to add that for a simple beam with vertical loads, if the left abutment sinks e ft., its vertical reaction R does the work $-R\,e$. The total sinking of any load, P, on the beam with reference to the ground, is made up of two parts, a part, Δ_1, due to the rotation of the straight beam about the right end, from the sinking of the left end e ft.; and a second part, Δ_2, due to the elastic deflection, referred to immovable abutments. Thus, the "external work" in this case is

$$-R\,e + \Sigma\,P\,(\Delta_1 + \Delta_2)$$

where the sum is to be taken for all the loads on the beam. Similarly, the case where both abutments sink can be dealt with. If both abutments sink an equal amount, then the external work is simply equal to $\Sigma\;(P\;\Delta_2)$.

If there is a restraining left-handed couple, whose moment is M_1, at the left end of a loaded beam and the vertical section thus turns α radians to the right, then it is easily shown that the work of the couple is $-\;M_1\;\alpha$. For gradually applied loads, the reaction and restraining couple will be gradually applied, so that the "exterior work" will be one-half of that given above, or

$$\frac{1}{2}\;[-\,R\,e - M_1\,\alpha + \Sigma\,P\,(\Delta_1 + \Delta_2)]$$

which must be equated to the "internal work"; or, the convenient derived formulas of Mr. Mensch may be applied. Mr. Cain.

Simply to illustrate the application of the general method, consider again the simple beam shown by the author's Fig. 3, which carries a single load P, distant a feet from the left abutment. Then, for immovable abutments, if Δ is the deflection at the load for a gradually applied load, the exterior work is $\frac{1}{2} P \Delta$, which equals the interior work

$$\frac{1}{2} \int_0^l \frac{M^2}{E I} dx$$

$$\therefore \Delta = \frac{1}{P} \int_0^l \frac{M^2}{E I} dx,$$

a well known formula.

Here to the left of the load

$$M = P \frac{l - a}{l} x;$$

to the right of the load

$$M = P \frac{a}{l} x.$$

Therefore

$$\Delta = \frac{P}{E I} \left[\int_0^a \frac{(l - a)^2}{l^2} x^2 \, dx + \int_0^{l-a} \frac{a^2}{l^2} x_1^2 \, dx_1 \right]$$

$$\therefore \Delta = \frac{P a^2 (l - a)^2}{3 E I l}.$$

To find α, the rotation of a vertical section at the load, pass a section through the beam just to the left of P and supply forces at the section equivalent to the action of the part of the beam to the right of the section on the part to the left, *viz.:* a left-handed couple whose moment is $P \frac{a (l - a)}{l}$, and a downward acting force, $P \frac{l - a}{l}$, Fig. 40.

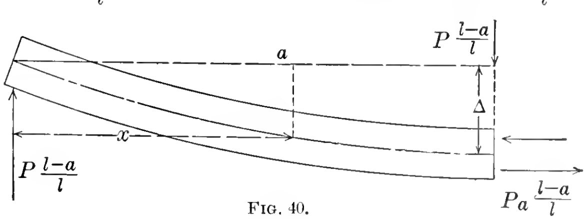

FIG. 40.

This latter force, with the left reaction, forms a couple of moment equal to that at the cut section; hence the system is one in equilibrium, and the exterior work equals the internal work, or

$$P \frac{l - a}{l} \Delta + \left(P a \frac{l - a}{l} \right) \alpha = \int_0^a \frac{M^2}{E I} dx.$$

Mr. Cain.

Substituting the value of Δ, derived above, writing

$$M = P \frac{l - a}{l} x$$

and, after effecting the integration, dividing through by $P a \frac{l - a}{l}$ and solving for α, there is obtained

$$\alpha = \frac{P a (l - a) (2 a - l)}{3 E I l}$$

exactly as given by the author.

Since $2 a < l$, α is negative; hence the vertical section under the load rotates α radians in an opposite direction to that of the couple there, or to the right.

This, of course, is not the shortest solution of this problem, but it is given to illustrate principles and incidentally to show that the ordinary formulas for beams with immovable abutments do not apply to the segment of the beams, with its loads and reactions, as given in Fig. 40. They do apply, however, to one half of the beam, when the load is at the center, to find the rotation of a vertical section at the abutment; for the half-beam is in the condition of a cantilever fixed at one end, with a horizontal tangent to the elastic curve, and loaded with P_2 at the abutment, acting upward, so that the solution, as in the case of the author's Case I, is quickly effected.

The writer, in conclusion, desires to express his great pleasure in reading the author's stimulating paper, which presents the subject so concisely and, at the same time, so clearly.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

CONTRACTS—A COMPARISON OF "COST PLUS" WITH OTHER FORMS

Discussion*

By Messrs. William E. Woolley, R. D. L. French, and J. W. Ledoux.

William E. Woolley,† Assoc. M. Am. Soc. C. E. (by letter).‡—On reading Mr. Wilder Clarke's paper, one concludes that he is an advocate of the "cost plus" system. The writer, however, cannot conceive the idea that the system will ever come into general use. Mr. Woolley.

An owner who intends to build naturally desires to know what he will have to pay, and when he may expect the work to be completed. One can say, in fact, that the first question asked is, "How much will the job cost?" How is the engineer to answer when the "cost plus" system is to be adopted? Under the older forms of contract, engineers and architects have been able in the past to answer these two questions fairly accurately, but now, owing to the constantly increasing cost of materials and labor, and the unsettled state of the labor market, we have made use of the "cost plus" system, under which many million pounds' worth of work has been carried out on this side of the water during the war.

In the opinion of the writer, we should regard it as a war emergency only. Under the "cost plus" system, or, as it is known here, the "prime cost plus profit" system, it is impossible to avoid decreased effort. There is no inducement to be economical or industrious. The writer holds that fair competition is a good thing. By competition the

* Discussion of the paper by Ernest Wilder Clarke, M. Am. Soc. C. E., continued from October-November-December, 1919, *Proceedings*.

† London, England.

‡ Received by the Secretary, February 3d, 1920.

Mr. Woolley. general level of effort is raised. One has only to think of the field of sports to arrive at this conclusion. The system is likely to have a disastrous effect on labor, there is no scope for tact in the management of men, there is constant interference and inspection on behalf of the owner, and there is no incentive to seize favorable opportunities of buying materials.

At the same time the writer admits that it is hardly to be expected contractors generally will take risks to the extent they have in the past. While we have the present unsettled conditions, and with charges all the while increasing, there should be appropriate clauses inserted in the contract allowing for variation in the contract price to meet the increased cost of materials and advances in wages. I cannot believe that the cost plus system will ever be extensively adopted either in this country or America under normal industrial conditions.

Mr. French. R. D. L. French,* Assoc. M. Am. Soc. C. E. (by letter).†—I have been much interested in the discussion of Mr. E. W. Clarke's paper on Contracts.

One of the prominent construction firms in this city has been employing the "cost plus percentage" contract with a rebate to the owner on the actual cost of the work. The following illustrations will make its mode of operations clear.

1. *Actual Cost Exceeds Estimated Cost:*

Estimated cost	$100 000
Estimated commission, 20% of estimated cost......	20,000
Actual cost	110 000
Rebate, 10% of actual cost......................	11 000
Commission earned, $20 000 — $11 000..............	9 000
Total cost to owner, $110 000 — $11 000 + $9 000....	108 000

2. *Actual Cost Less Than Estimated Cost:*

Estimated cost	$100 000
Estimated commission, 20% of estimated cost......	20 000
Actual cost	92 000
Rebate, 10% of actual cost......................	9 200
Commission earned, $20 000 — $9 200..............	10 800
Total cost to owner, $92 000 — $9 200 + $10 800.....	93 600

I am informed that this contract has given satisfaction in the few cases it has been used, and it appears to do away with one of the objections to the straight "cost plus percentage" form, in that the contractor has some incentive to keep the cost of the work down.

* Montreal, Que.

† Received by the Secretary, January 13th, 1920.

Mr. Ledoux.

J. W. Ledoux,* M. Am. Soc. C. E. (by letter).†—Mr. Clarke has presented exhaustively the merits of the "cost plus" system of letting contracts. Under ideal conditions, where the contractor and his force are actuated by fairness and honesty, the system is undoubtedly equitable to both the contractor and the owner, but there is enough evidence in the administration of recent contracts, especially in most of those carried out during and continuing after the War, to prove that the system is capable of the greatest injustice to the owner, and profiteering. Even where the contractor himself may desire to be fair to his principal, the very fact that it is to his advantage to have the work extend over a long period and cost more than the estimate, permeates the entire organization from the superintendents to the lowest paid laborers. It takes away all the responsibility and the impetus for despatch and economical construction.

The writer ventures to say that many of the most important projects carried out on this system might have been done for one-third or one-half the cost under a system that would have been to the interest of the contractor to finish the work in the shortest time and at the lowest cost, which is the ideal system. No one has been able to devise a form of contract that will realize this ideal.

Therefore, any system that is recommended must be defective in some part.

The usual contracting systems are: The "Lump Sum", the "Unit Price", the "Cost Plus a Percentage", and the "Cost Plus a Fixed Sum". Some projects lend themselves to the lump sum bid; such, for instance, as the construction of a pumping engine, a water tower or a light house, where there may be no subsequent necessity for deviating from the original plans. The lump sum bid is not well suited to the construction of a dam or reservoir or any structure where the quantities are likely to differ from those shown in the original plans, in which cases the unit price system is applicable. Both of these systems, however, give the owner the advantage and impose upon the contractor serious risks. If the work be let to the lowest bidder he must often compete against unduly low bids. If he gets the work he takes all risk of unfavorable conditions, while the owner takes only the risk of increased quantities. In the percentage and cost plus methods there is a premium on inefficiency and profiteering, and the advantages lie wholly with the contractor, who takes no risk whatever.

Engineers have tried to overcome these difficulties without imposing injustice on the contractor. Probably one of the best methods is to invite bids on a unit price basis, with the proviso that the most acceptable bidder is to be willing to take the work as an alternate on a fixed

* Philadelphia, Pa.

† Received by the Secretary, February 5th, 1920.

Mr. Ledoux. profit basis. Then the owner, through his engineer, may call in the acceptable bidder and decide on the amount of profit he is willing to pay, regardless of the cost; the work is done on a cost basis plus the fixed profit, and the contractor is permitted to participate in the saving in cost to the extent of 25 to 50 per cent. This bonus will be sufficient to induce the contractor to expedite the work as much as possible and it will be to the interest of every one connected with the construction to do the work at the lowest price and in the shortest time. This method may appear difficult of application, but the difficulties are more apparent than real. A complete understanding must be had with the contractor as to whether, and how, overhead charges and plant rental are to be included in cost.

Another method of overcoming the difficulty is to select a contractor who has established a reputation for economical construction on the "cost plus" basis, but this method is manifestly unfair to many deserving contractors whose reputations are not so well known.

In any case, the interests of the owner in regard to quality of work can be safeguarded only by honest and capable engineering supervision.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

THE PRODUCTION OF TOLUOL FROM GAS PLANTS

Discussion*

By A. C. Klein and Horace C. Porter.

A. C. Klein† (by letter).‡—In addition to the experience in reducing the candle-power of New York City gas, the Ordnance Department, in its operation of the Government toluol plants, was confronted with similar problems in the cities of Minneapolis and Detroit. Mr. Klein.

In Detroit, the Gas Company was required to deliver gas of 20 candle-power and 600 B.t.u. Late in 1917, representatives of the Ordnance Department requested the authorities to reduce the candle-power, so as to permit the recovery of toluol at two plants, as contemplated. The City Council adopted a resolution reducing the standard to 12 candle-power and 600 B.t.u. during the operation of the toluol plant. The heating value standard was later reduced to 570 B.t.u., and although these standards were maintained until after the armistice, no record of any complaints was brought to the attention of the Ordnance Department, which was in constant touch with the plant operation, and particularly on the lookout for dissatisfied gas consumers.

The gas standard in Minneapolis, prior to the war, was 16 candle-power and 600 B.t.u. After negotiations for the operation of a toluol plant had been completed, the City Council was requested to reduce the standard to 10 candle-power, so as to permit the operation of the plant without the use of additional gas oil. The Commission acceded to this request, and later further reduced the standard to 10 candle-power and 570 B.t.u., at which it remained until the toluol plant was shut down by the Ordnance Department. As in New York and Detroit,

* Discussion of the paper by Myron S. Falk, published in the October-November-December, 1919, *Proceedings*.

† Philadelphia, Pa.

‡ Received by the Secretary, January 30th, 1920.

Mr. Klein. no complaints of poor gas service had come to the attention of the Government Inspectors.

To the casual reader of Mr. Falk's paper, it would appear that the Ordnance Department occupied an anomalous position in requesting a reduction in gas standards on the one hand, and in opposing a reduction on the other. There was, however, nothing inconsistent in its attitude. Its only concern was to obtain the maximum amount of toluol, so that the T. N. T. plants might be kept operating at 100% capacity. Therefore, whenever a lower gas standard was necessary to permit toluol to be extracted, the Ordnance Department advocated a lower standard; when a lower standard would result in curtailing the toluol production (as would have been the case had the 528 B.t.u. order been put in force), the Ordnance Department opposed such a reduction.

This narrative of the action of the Ordnance Department in bringing about a material reduction in candle-power of the gas delivered in several of our largest cities, and its failure to affect adversely the interests of the gas consumers of those cities will be of great interest to the gas industry.

For many years gas engineers have advocated that all candle-power standards be discarded, so that they might be enabled to take advantage of economical methods of gas manufacture and distribution, which they are unable to use when obliged to conform with high candle-power standards. Practically all regulatory bodies have recognized the soundness of this stand, and have substituted heating-value standards, setting them low enough to encourage the utilization of gas from by-product coke plants. However, our largest cities have been the ones to cling to the obsolete candle-power standard, claiming that a considerable number of gas users are dependent upon open flame lighting, and would suffer by a reduction in candle-power.

The experience in New York City, where the candle-power was dropped from 22 to 10, or 55%, without complaint from consumers, shows that there is no longer any good reason for retaining a candle-power standard. Standards of any kind are intended to serve the purpose of insuring to the purchaser a uniform quality of product, which quality should be as high as possible consistent with its price. In cases such as that of a public utility, where the price paid by the consumer is determined by representatives of the commonwealth, the fair price necessarily bears a direct ratio to the cost of production, and public interest, therefore, demands that the standards should be such as to keep this cost of production as low as possible. The candle-power standard does not meet this test, and it should, therefore, be discarded.

In considering the question of gas standards, regulatory bodies should have broad enough vision to see the future sources of gas supply.

Our requirements for smokeless fuel are increasing at a very rapid rate, while the production of anthracite is increasing little, or none.

The shortage can be made up by the use of coke for domestic purposes. Coke is today a formidable competitor of anthracite, and the extension of its use will tend to keep anthracite prices down. The manufacture of coke in modern oven or retort plants yields a by-product gas, which is in every way satisfactory for domestic cooking, heating and lighting, although it cannot be manufactured to meet a high candle-power standard. Today, more than a score of large cities, including St. Louis, Boston, Baltimore, Newark, Jersey City, Indianapolis, St. Paul, Hartford, Providence, Rochester, etc., are being supplied wholly or in part by such gas. None of the cities mentioned has a candle-power standard. Mr. Klein.

The authorities who are charged with the responsibility for protecting the interests of the public served by public utilities, and who have not yet recognized the wastefulness of the candle-power standard, should give full weight to the points brought out in Mr. Falk's paper, and should set standards of gas quality that will encourage the construction of large coal-gas plants. By so doing, they will be instrumental in creating a source of economical gas, as well as a source of smokeless fuel, which will act as a check upon the rapidly mounting prices of anthracite fuel.

Horace C. Porter,* (by letter).†—The paper is particularly illuminating on the relationship of toluol production during the War to required standards for city gas. The author is to be congratulated on his clear and forceful presentation of the facts bearing upon the treatment of this question by the War Department and the Fuel Administration during the war. Mr. Porter.

Attention may be called to an additional item, not mentioned by the author, in the increase of toluol production accomplished by the Ordnance Department. The coke ovens which at the beginning of the war produced 85% of the toluol supply were assisted in obtaining coal of good quality, and in raising their yield of toluol per ton. An increase of over 10% was thus obtained in their production, and four times that increase would have been possible with intensive effort and due co-operation on the part of all governmental agencies concerned.

The average production of toluol per ton of coal by coke oven plants throughout the country was at the beginning of the war about 0.28 gal. During the year 1918, up to November 1st, 10 plants (out of a total of 35) averaged 0.44 gal. per ton of coal. The highest was 0.56 gal. With a coal mixture of reasonably high percentage of volatile matter (having regard for necessary coke output) and with reasonably practical changes in operating conditions, the average yield of toluol from coke ovens throughout the country could have been increased to 0.40 gal. per ton, or by 40 per cent.

*West Conshohocken, Pa.

†Received by the Secretary, February 10th, 1920.

Mr. Porter. In December, 1917, the Fuel Administration was urgently requested by the Ordnance Department to take steps toward preventing the diversion of high-volatile coal from coke oven plants, and to insure to these plants a full coal supply so as to maintain toluol and ammonia production. Belated steps were taken in this direction, but the results were not in evidence for several months.

The development of toluol supply from city gas plants was resorted to in the early days of the war because it would relieve the situation quickly. The old saying reminds us that "hindsight is better than foresight", but as we look back in the light of later experience it appears unquestionably true that the utilization of existing coke oven capacity for toluol production at the highest possible efficiency and with fullest possible coal supply of highest percentage volatile matter would have yielded a large increase in toluol in a short time, and would have rendered unnecessary some of the more expensive of the Government installations at gas works. Coke oven plants under construction at the beginning of the war could also have been hurried to completion and their toluol production made available earlier.

Coke oven plants and their benzol-toluol recovery equipment have a good post-war value, while city gas stripping plants have little or none. Conservation is promoted by the former, disturbed by the latter.

Had the Fuel Administration not failed to provide the coke ovens with the necessary coal for full toluol production in the early stages of the war, there would have been better ground for their subsequent plea for oil conservation at gas plants through the 528 B.t.u. standard and consequent toluol reduction.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE SILT PROBLEM OF THE ZUNI RESERVOIR
Discussion*

By Clarence S. Jarvis.

Clarence S. Jarvis,† Assoc. M. Am. Soc. C. E. (by letter).‡—Due to the deterring influence that will be exerted on meritorious irrigation projects now under way or about to be undertaken, as well as to the discouraging effect on the stockholders of existing systems pending a satisfactory solution for each enterprise where the silt problem is a serious menace, the subject dealt with in this paper has increased in immediate importance with the publishing of such conclusive data as are furnished by the author. The unfortunate condition that obtains concerning the relative aridity and the silt-bearing power of the streams, the greatest erosion usually taking place during the torrential run-off from the barren, parched slopes at the time of those occasional fitful downpours or "cloudbursts" indigenous to the Southwestern States, producing temporary rivers in the desert for a few hours, serves to increase the difficulty; for where it is most important to conserve the entire flood run-off and to maintain the maximum depth of storage to reduce evaporation, the introduction of vast quantities of sediment not only reduces the available storage capacity, but also increases the relative loss from evaporation, due to the increasing shallowness. Mr. Jarvis.

Factors that will enter into the solution or discussion of the problem, such as the relative quantities of water to be stored compared with the quantities passing the dam site, the gradient of the drainage and irrigation channels, the character of the sediment, the accessibility of the reservoir site for the delivery of construction materials and equipment, the limiting heights for the future storage, and the productivity of the land served with water under the various irrigation systems, will vary so widely as to require an independent solution for each case.

* Discussion of the paper by H. F. Robinson, Assoc. M. Am. Soc. C. E., continued from October–November–December, 1919, *Proceedings*.

† Capt., Engrs., U. S. A., Benicia, Cal.

‡ Received by the Secretary, January 23d, 1920.

Mr. Jarvis.

Apparent and Actual Capacities.—It is well established that the actual yield of a reservoir may be greatly in excess of the apparent capacity, due to the lateral extension of the stored water into the loose talus slopes so common to mountain valleys, or in some cases to the lateral infiltration into great depths of permeable soil. Inspection of the recently uncovered slopes of a receding reservoir will disclose numerous seeps and springs yielding the water from the underground reservoir, which represents the difference between the apparent and actual capacities. The writer has observed that, in the case of numerous glacial moraines on the borders of mountain lakes being converted into reservoirs, the excess storage capacity thus obtained in basins ranging from a few acres to more than a hundred acres amounted to from 5 to 20% of the apparent capacity. Also, the apparent capacity of a river valley filled with rock detritus and sediment is practically nothing; yet the wonderful success of submerged dams for the purpose of bringing the underflow from such river deposits to the surface, proves that the safest and best reservoir sites, unaffected by the usual evaporation losses, are in the voids of sedimentary deposits. Perennial springs issuing from nearly horizontally stratified rock, or even from talus slopes on mountain sides, are occasionally successfully retained during the non-irrigation period, with a resultant increased flow when released.

While the percentages of voids in sedimentary deposits may vary from 40% for clean gravel and sand to 20% for fine silt, and in extreme cases the range may be outside of these limits, the actual yield for stream flow may amount to nearly 40% in the case of coarse material, and to practically nothing in the case of fine silt. In the latter case, the main losses of moisture are by surface evaporation, which is rendered continuous through capillary attraction until all of the excess or free moisture is removed from the sediment; while the seepage is so slight as to be lost by evaporation.

It is evident that a reservoir completely filled with clean coarse sand and gravel might retain from 30 to 40% of the original volume for effective storage, while the same basin filled with fine silt, or with coarse sediment mixed with enough fine silt to produce the maximum density, would retain possibly 15% of voids, but might yield less than 5% of the original volume of storage.

Removal of Sediment.—The ordinary methods of excavation with standard equipment, at several reservoir sites where the writer has been engaged as engineer, have resulted in an average cost varying from \$1.00 to \$0.10 per cubic yard of earth in large deposits. Using the lower unit price, the cost of removing 1 acre-ft. of sediment, approximately 1 600 cu. yd., would be \$160, which could not be justified under current irrigation practice. The original cost per acre-foot of storage capacity in successful irrigation projects may run as high as \$50, or as low as \$2; with the rise in values of property in irrigation districts

and with the reduction of maintenance expense on the canal systems, larger annual appropriations may be diverted each year for the recovery and maintenance of storage capacity, but a low unit cost for handling the material is imperative. Mr. Jarvis.

Apparently the only method that may be used successfully for this purpose is some adaptation of hydraulic sluicing. The cost of pumping 1 acre-ft. of water against 100-ft. head, with power delivered at 1 cent per kw.-hr., and an efficiency over-all of only 50% is slightly less than $2 for power. If the water carries a burden of fine sediment amounting to 15% by weight or 10% by volume, then the power charge for such pumping will amount to approximately $20 per acre-foot of dry sediment. It is not unusual for the plant and operation charge to equal the power charge; therefore, under such conditions, the cost per acre-foot of sediment removed would be $40. Fortunately, the sediment is seldom required to be elevated as much as 100 ft.; it is usually sluiced out by way of the lowest channel, and the percentage of sediment carried need not be limited to 10% by volume if appropriate grades and equipment are used.

Consider now the type of reservoir ordinarily provided in the channel of a stream. For this case, assume an elongated site with a steep gradient in the channel, a high dam, and a stream run-off two or three times the original volume of the storage. Proper manipulation of the outlet gates, which should be of ample dimensions, together with judicious use of hydraulic pumps and jets from hydraulic giants mounted on a barge for use around the edges of the reservoir during the irrigation season and especially while the surface of the water is receding, reducing the larger deposits of silt and maintaining a turbid outflow, could be so adjusted as to keep pace with and correct the silting process. The alluvial silt thus distributed upon the irrigated land would be of immense value as a fertilizer; the canal system would have less percolation losses, and there would be less likelihood of the canal breaking than where clear water is used.

Under some conditions the plan suggested by Mr. W. W. Follett for combating the sedimentation menace at the Elephant Butte Reservoir might be advisable. This consisted of a conduit constructed in the bed of the reservoir and connecting the outlet with the Narrows about midway along the axis of the basin. This conduit would convey the sediment from the up-stream portion of the site to the outlet without allowing it to be deposited within the down-stream portion at any time. The up-stream area would therefore be an effective silt pocket for the main storage basin, and insure the delivery of turbid water for irrigation purposes. With such a conduit constructed through a reservoir site and provided with standpipe connections at intervals, the practical plan suggested by J. H. Quinton, M. Am. Soc. C. E., as Consulting Engineer for the Zuni Reservoir project, as related at the

Mr. Jarvis. conclusion of the paper, the desilting of a reservoir site would be economically and effectively accomplished, under ordinary conditions.

The type of reservoir that has no waste outflow lacks the advantage of the channel sluicing; but in other essentials the problem is similar to that above described.

The preferable way to prevent excessive sedimentation is to reduce erosion; but this method certainly has its limitations. There is no doubt that the habits of some streams could be modified in this particular by planting suitable trees, willows, shrubs, and other vegetation, and protecting the banks against lateral erosion by barriers and deflecting structures wisely placed; and the value of the timber thus grown in the unforested regions would go a long way toward compensation for such improvements. The natural processes of erosion, however, will continue to some extent; and wherever reservoirs occupy the stream channel the burden of sediment must either be diverted, carried through by some natural or artificial sluicing, or else the reduction of storage capacity must be included in the reckoning.

Conclusions.—The writer cannot concur in the view expressed by Elwood Mead, M. Am. Soc. C. E., in his discussion* of this paper, to the effect that the desert places should have remained barren until some feasible plan of desilting was worked out. If the future of the irrigation projects now most seriously beset with trouble from sediment should necessarily include abandonment, then the views so clearly expressed by Mr. Mead would meet with universal approval. Taking into account the influence of reservoirs upon the habits of a river, cutting off the peaks from floods and distributing some percentage of the flow that would otherwise be wasted to lands from which the underflow, when definitely established as the result of irrigation, will continue steadily for months or even years, one must conclude that the service from such reservoirs in establishing underground reservoirs of increasing capacity, compensates in part for the loss of capacity due to sedimentation. So important is the seepage flow as the result of irrigation that it is not uncommon for the owners of such projects to specify in the contracts of sale to homeseekers that the resulting seepage water may be collected by the distributing company and used as an integral part of the water supply for the project. The writer has observed that, where water was used copiously upon bench or plateau lands, the visible return flow became considerable after four or five years; and lands at lower elevation within the same project were being supplied in part from this source.

Reservoirs of elongated form along the main channel, through which large floods may flow freely for considerable periods, and which can be filled with the remaining flow after the stream has clarified in large measure, can be regarded as permanent and of practically con-

* *Proceedings*, Am. Soc. C. E., October–November–December, 1919, p. 889.

stant capacity, irrespective of the quantity or character of the silt, as has been demonstrated in the Assuan Reservoir on the Nile. Inasmuch, however, as the regular and dependable habits of the Nile place this reservoir in a class by itself, the miniature reservoir projects that resemble the Assuan in essential features will require a somewhat modified treatment, and with varying degrees of success. Mr. Jarvis.

The main river channel through an elongated reservoir site represents a greater percentage of the original capacity than is realized at first consideration; and there can hardly be a well-founded claim that this portion of the reservoir will become a level mud flat. Some lateral erosion will occur naturally if the reservoir gates, of ample size, may be kept open for considerable periods, and this result would be obtained by the direct sluicing of the natural stream.

Departure from the simple process of direct sluicing through a reservoir basin immediately involves additional equipment or structures, such as conduits, pipe lines, pumping plants, barges, etc.; and it would be necessary to make thorough study and skillful designs to avoid the uncertainties of experimentation. But reduced to the simple requirement that the average silt content of the outflow shall be equal to the average burden of the inflow, the problem is capable of satisfactory solution in all except the extreme cases. The popular notion of the sediment carried by a stream is often based upon the observation of the maximum burden. The Rio Grande with an average silt content of 1.66%, and the Gila with an average of 1.3% during years of observation, have to receive and carry on the occasional contributions of liquid mud from their tributaries; and without the published data obtained by reliable observers, it is certain that a much higher silt content would be credited to these rivers by those who had casually observed the heavy floods.

The silt problem along the rivers of the Southwest is not more serious than the drainage problems that arise in irrigated districts; yet settlers and land owners and engineers cheerfully accept the challenge of these two lurking enemies of the irrigation project. Too often the first cost of the system so far overruns the estimate that there are no funds available, during the first years of operation, to give the needed attention to these matters; but it is fully realized that the accumulation of sediment in the one case, or the accumulation of seepage water in the lower lands and subsoil in the other case, increases year by year; and perhaps after ten years or twenty, or a longer period, when disaster is threatening the enterprise, pronounced steps have to be taken to correct the trouble and relieve an accumulation that should have been taken care of as a part of the maintenance of the project.

Mr. Robinson and Mr. Mead have rendered a distinct service to the Profession in presenting the data and views on this important topic.

MEMOIRS OF DECEASED MEMBERS

Note.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

WILLIAM ARCHER, M. Am. Soc. C. E.*

Died November 24th, 1919.

William Archer was born at Penrith, England, on June 7th, 1844, and came to the United States with his parents in 1850. The Archer family settled at Cleves, Ohio, in the early Fifties, and Mr. Archer made the little suburb of Cincinnati his home for the remainder of his life. After securing his elementary education, he attended Farmers' College at College Hill, Ohio, taking a Liberal Arts Course, but specializing in all the mathematical and scientific courses available.

After spending four years as Assistant Engineer with the "Big Four" Railroad, he entered the service of the West Virginia and Ohio Railroad (now a part of the Baltimore and Ohio) in May, 1869; his active service with the Baltimore and Ohio Railroad System from that date until his death was never severed—a period of more than fifty years. He held positions, successively, as Engineer of Location and Construction; Assistant Engineer; Division Engineer; Principal Assistant Engineer, Maintenance of Way; Assistant Real Estate Agent, and Assistant Engineer in an advisory capacity, which position he held at the time of his death.

Fifty years of continuous active service, beginning with the construction of the railroad west of the Ohio River, gave Mr. Archer an almost unparalleled knowledge of the Western Lines; a wonderful memory, together with an unusual gift for assembling facts in an orderly and concise manner, enabled him to use this knowledge most effectively.

As Assistant Engineer in an advisory capacity, Mr. Archer's knowledge, together with his eagerness to assist all who came to him, made his services invaluable for the securing of historical and statistical data.

Mr. Archer was elected a Member of the American Society of Civil Engineers on March 2d, 1881; he was a charter member of The American Railway Engineering Association.

* Memoir prepared from information on file at the Headquarters of the Society.

STEPHEN PEARSON BROWN, M. Am. Soc. C. E.*

DIED DECEMBER 6TH, 1919.

Stephen Pearson Brown, the son of Stephen O. and Mary P. Brown, was born at Dover, Me., on April 29th, 1877. After graduation from the Hotchkiss School, Lakeville, Conn., in 1896, he studied a short time in Heidelberg, Germany, and entered the Massachusetts Institute of Technology, from which he was graduated in 1900, with the degree of Bachelor of Science.

Immediately after his graduation Mr. Brown was employed in making tests of lubricating oils under mill conditions for the Washington Mills, Lawrence, Mass. From 1901 to 1903, he was junior partner of the firm of Collier and Brown, Consulting Engineers, Atlanta, Ga., having charge of the mechanical and civil engineering work in hydroelectric developments, sewerage systems, water-works systems, mine developments and factory and electric plant designs. In 1904, he had charge of the construction of the depot at Bridgeport, Conn., under the Architect for the New York, New Haven and Hudson River Railroad Company, and, in 1905, designed reinforced concrete structures for the Columbian Fireproofing Company of New York City.

On August 1st, 1905, Mr. Brown joined the organization of the United Engineering and Contracting Company of New York City, as Engineer of Construction on the St. Mary's Park Tunnel and the Port Morris depression of the Port Morris Branch of the New York Central Railway. This company late in 1905 sent Mr. Brown to Porto Rico to investigate and report on conditions relating to municipal water-works, water supply, electric light and power from a possible water-power plant, and a sewerage system, all for the City of San Juan, Porto Rico. From 1906 to July, 1908, he had charge of the work of the same company on the Pennsylvania Railroad Company's cross-town tunnels, supervising all work west of Fifth Avenue, New York City.

The last half of 1908 Mr. Brown spent in Europe, investigating foreign practice in hydraulic and tunnel work. He returned to the United Engineering and Contracting Company in January, 1909, as Principal Assistant Engineer, and also acted as Designing Engineer for the Cuban Engineering and Contracting Company, of New York City, up to July of that year, when he returned to Europe for six months' study of tunneling methods. From 1910 to 1912, he was Chief Engineer for the Tidewater Building Company and T. B. Bryson on the Fourth Avenue Subway, New York City.

From 1912 to 1917, Mr. Brown served as Chief Engineer of the Mount Royal Tunnel and Terminal Company, Limited, and Managing

* Memoir prepared from information on file at the Headquarters of the Society.

Engineer for Mackenzie, Mann and Company, Limited, having charge of both design and construction of the terminal development in Montreal, Que., Canada, for the Canadian Northern Railway. This included a double-track tunnel more than 3 miles long, elaborate freight and passenger terminals and an elevated double-track viaduct across the lower town from the tunnel to the harbor. It involved an estimated expenditure of about $15 000 000, and $10 000 000 was actually expended.

From 1918 to June, 1919, Mr. Brown was Vice-President and General Manager of the Ford, Bacon and Davis Corporation, Engineers, and was active in the Construction Department of the International Coal Products Corporation on a Government carbo-coal and by-product plant.

Mr. Brown was a member of the following engineering societies: American Society of Mechanical Engineers, American Railway Engineering Association, Engineering Institute of Canada, Institution of Civil Engineers (Great Britain). He was also a member of The Engineers Club, and The University Club, both of New York City.

Mr. Brown met his death at Sebec Lake, Maine, when he broke through the ice on which he was crossing to his summer home near Greeley's Landing. He directed his son, whom he had been hauling on a moose-sled, to run to the shore and down to the houses at the landing to give the alarm. The child did so and found two women, but before they could reach him, Mr. Brown had become exhausted and had sunk beneath the ice. As soon as word reached the village a party went to the landing and the body was recovered that night.

He is survived by his wife, who was Miss Edith Luce, of Boston, Mass., and two sons, his mother, and two sisters, Mrs. J. Arnold Norcross, of New Haven, Conn., and Mrs. Clarence F. Dore, of Melrose, Mass.

Mr. Brown was elected an Associate Member of the American Society of Civil Engineers on October 5th, 1904, and a Member on November 1st, 1910.

PAUL SOURIN KING, M. Am. Soc. C. E.*

DIED OCTOBER 30TH, 1919.

Paul Sourin King was born at Philadelphia, Pa., on March 16th, 1845. Until he was fourteen years old, he was seriously hampered by the fact that he was crippled in both legs. As a boy he attended the public schools and, later, went to a small college in Westmoreland County, near Greensburg, Pa., but he was largely self-educated.

* Memoir prepared from information furnished by Henry King, Esq., and on file at the Headquarters of the Society.

At the age of seventeen, Mr. King was employed by Herman Fisher, a Mining Engineer, at Ashland, Schuylkill County, Pa., with whom he stayed about one year. In 1865, he was engaged as Rodman with the Locating Corps of the Mahonoy and Broad Mountain Division of the Philadelphia and Reading Railroad, under Charles E. Byers, Chief Engineer, principally on work connected with the Port Clinton, Hamburg, and Kutztown Branch, and other branches of the road, until 1870.

From 1871 to 1875, Mr. King served as Chief Engineer of the Roanoke Valley Railroad Company, on the construction of 53 miles of that line in Virginia, his headquarters during this time being at Richmond, Va.

In 1875 and 1876, he was engaged as Engineer in charge of the Virginia and Gold Hill Water-Works Extension, on the location and construction of a tunnel through the Sierra Nevada Mountains, as well as a pipe line, dams, etc., in the State of Nevada, and from 1877 to 1879, he was employed as Chief Engineer of the Union Island Reclamation Company on the location and construction of 30 miles of levee work, piling, damming sloughs, etc., in California.

In 1880, Mr. King went to Mexico as Assistant Engineer on the location of the Mountain Division of the Mexican National Railroad, and remained there until 1881. On his return to the United States, he was engaged with Messrs. Oliver Barnes and Charles McFadden, who, at that time, were grading about 30 miles of road in Elk, McClain and Clearfield Counties in Pennsylvania. He was also employed as Division Engineer on the Pittsburgh, Youngstown, and Chicago Railroad, on the location of the Ohio River Bridge crossing, etc., in Pennsylvania.

About this time the construction of the South Pennsylvania Railroad, from Harrisburg to Pittsburgh, was under way, and Mr. King was appointed Division Engineer on the location of the road through the Blue Mountain Section in Pennsylvania.

Mr. Robert H. Sears, Chief Engineer of the Lehigh Valley Railroad, recommended Mr. King to the President of the Bethlehem Coal and Iron Company, and, in 1883, he was sent by the latter Company to Cuba as Chief Engineer of the Juragua Iron Company, Limited, Railroad, on the location and reconstruction of 18 miles of difficult mountain road, as well as bridges and a pier, for loading iron ore in the harbor of Santiago, Cuba.

On his return from Cuba in 1885, Mr. King was engaged by the Lehigh Valley Railroad Company to build a branch of that road between Buffalo and Geneva, N. Y., of which work he was Chief Engineer.

On the completion of this work, he established an office for the private practice of engineering as Consulting Engineer in New York City, which he maintained for more than 15 years. During this period, he went to South America with the editor of *Engineering News* and, in addition, traveled extensively, attending practically all the Worlds' Fairs.

Although, as has been stated, Mr. King was crippled in the early years of his life, he had recovered entirely from this condition; in fact, he frequently stated that he could outwalk any man in his party. He had never married.

Mr. King was elected a Member of the American Society of Civil Engineers on July 3d, 1889.

EDGAR MARBURG, M. Am. Soc. C. E.*

Died June 27th, 1918.

Edgar Marburg was born on March 4th, 1864, at Hamburg, Germany, where his father had sent his family from New Orleans during the Civil War. His father, Herman Edward Marburg, was a man of artistic tastes and a lover of arts, who had planned to devote himself to languages but who finally engaged in business and succeeded so well that he became a wholesale merchant. He came to America in 1847, representing a Hamburg firm, and became a naturalized citizen in 1853. His mother, Clara Juergesen Marburg, was also a native of Germany, Edgar Marburg was third in a family of four sons and two daughters, all of whom—including both parents—have survived him.

In early life, Dr. Marburg showed those characteristics of independence of thought and action that marked his later life. It is related that at the age of five years, by a series of questions which he asked his mother and by reasoning the matter out entirely by himself, he learned to tell the time.

He attended private schools in New Orleans and later in Shreveport, La., and from the beginning showed much aptitude for study, particularly for mathematics. His teacher at Shreveport, Capt. George E. Thacher, soon recognized his mathematical ability and placed him in a class by himself in that subject, with no lesson assignments. Young Marburg would simply report from time to time how far he had progressed in his study. His family have to-day a book in which he kept, in neat, orderly arrangement, solutions of many problems, from simple ones in arithmetic to those in analytic mechanics and calculus. He made it a rule never to ask or accept help on any problem, and this self-reliant attitude was evident throughout his life in everything he undertook.

At the age of fifteen he gave up school and announced his intention of going to college. It was necessary for him largely to work his way through, and he accordingly worked for the next three years in a large

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* Memoir prepared by Samuel Tobias Wagner, M. Am. Soc. C. E., and Charles Laurence Warwick, Jun. Am. Soc. C. E

wholesale grocery store in Shreveport. He studied at nights to prepare to enter the sophomore class at college. Upon the advice of Capt. Thacher, and because of his predilection for mathematics, he decided to study Engineering and finally entered Rensselaer Polytechnic Institute in 1882 as a sophomore, at the age of eighteen. The promise of his early youth was fulfilled in his college life, and he graduated with the degree of Civil Engineer in 1885.

Of his college days the following letters bear testimony to his activities and character at that time. Mr. Enrique A. Touceda, M. Am. Soc. C. E., writes as follows:

"While he was always intensely interested in Institute happenings and was always popular with the student body, and particularly so with his classmates, he was modest and more or less retiring, having little to do with Institute politics. Without being what is known as a 'grind,' his first thought was to make good in his studies and then to devote as much time as possible to the enjoyment of general college life. During this period little if any attention was paid by any of the students to athletic sports, first due to lack of time, and second to the fact that the Institute possessed no athletic field.

"Marburg as a youth was appreciated by his associates as one of sterling worth, very interesting and very companionable. He was intellectually vigorous and quick of judgment; always dependable and ready to render a friendly service on the instant."

Dr. Palmer C. Ricketts, M. Am. Soc. C. E., President of the Institute, writes:

"Marburg, of course, was a very excellent student while here. He was graduated with the degree of Civil Engineer in the Class of 1885. He was a member of the Rensselaer Society of Engineers when a student and was the first editor of the Institute Quarterly, a paper which had a brief existence. * * * We all liked him when he was a student here and after he was graduated. He was a very able man, a man of fine integrity and of fine disposition."

He had definitely decided at this time to specialize in structural engineering and aimed to obtain as varied an experience as possible. Consequently he adopted the plan of going from one bridge or structural company to another, studying at each one until he had the experience he desired. These changes were at times made at a loss of salary, but this feature never swerved him from his determination. In his later associations with young graduates, Dr. Marburg always endeavored to impress on them the importance of gaining experience in their profession and cautioned them against making increase in salary their sole consideration in changing positions.

In 1885 he entered the employ of the Keystone Bridge Co. at Pittsburgh, Pa., and remained there until about 1887. Mr. Edwin Thacher, M. Am. Soc. C. E., who was then Chief Engineer, writes as follows regarding this engagement:

"I was Chief Engineer of the Keystone Bridge Co. in Pittsburgh in 1885 when Mr. Marburg graduated from the Rensselaer Polytechnic Institute at Troy. He had applied for a position a month or more previously and I told him to come on if he was willing to start in at a salary of $50 per month, which was paid to all beginners. He came at the appointed time, and I set him at work on the design of plate girder bridges, at which he soon became expert. He was kept on this line of work for nearly a year, much longer than he should have been for his own good, for I believe it is the practice in all large bridge drafting rooms to keep a man at the class of work that he is most expert in; but finally Mr. Marburg before he left did get considerable experience in the design of pin connected bridges and buildings.

"I was very favorably impressed with Mr. Marburg from the first day I saw him. His appearance and bearing were such as to satisfy me that he was a young man of superior ability, and of all the men in the drafting room he was my favorite. He had no bad habits and was a conscientious worker."

From 1887 to about 1889 he was in the employ of the Phoenix Bridge Co. at Phoenixville, Pa., employed almost entirely in the computing department of that company. From 1889 to 1900 he was with the Edgemoor Iron Co., at Wilmington, Del., in the designing and estimating department under C. W. Bryan, M. Am. Soc. C. E., now Chief Engineer of the American Bridge Company.

In 1891 he returned to his home in Shreveport and it was at that time that he met and became engaged to his future wife, Miss Fanny Dulany Moncure. In 1891 and 1892 he was in the employ of the Carnegie Steel Co. (Keystone Bridge Co.) at Chicago, Ill., under Mr. Charles L. Strobel, M. Am. Soc. C. E., who writes as follows as to his work at that time:

"Mr. Marburg was employed by the Keystone Bridge Co. (one of the Carnegie firms), Chicago office, in 1891-92, which office was in my charge. I was at the time Consulting Engineer of the Keystone Bridge Company and of Carnegie, Phipps and Co., Limited. Dr. Marburg was engaged upon the work of preparing shop and mill plans for the structural iron work required for the large fireproof Auditorium Building, Chicago. This was unusually complicated work, as the building was designed to serve several purposes—part to be a concert, opera and convention hall, another part to be an office building and a third part to be a hotel. It was necessary to do the work under great pressure as to time, in order to permit the use of the large hall for the meeting of the National Republican Convention in the fall of 1892. Dr. Marburg was earlier employed in connection with a revised edition of the Carnegie, Phipps and Co. Handbook, then in preparation.

"Dr. Marburg's splendid qualities of conscientiousness, thoroughness, faithfulness and competency were in evidence, as they have so conspicuously been in his later life."

In 1892 a number of engineers recommended him to Dr. Charles Custis Harrison, then Provost of the University of Pennsylvania, for the

position of Professor of Civil Engineering at that institution. He was elected Acting Professor of Civil Engineering and a year later became full Professor, a position which he held until his death.

Possibly no one is better qualified to speak of his qualities as a teacher than William Easby, Jr., M. Am. Soc. C. E., who was associated with him for many years at the University of Pennsylvania.

"Few have left a stronger impress of their personality on a life's work than has Edgar Marburg, for twenty-six years Professor-in-charge of the Department of Civil Engineering. Throughout this long period, covering years of devoted service, he gave unstintingly of the best that was in him toward the upbuilding of the department so wisely entrusted to his charge. That he was successful is well known and strikingly apparent to any who can compare the curriculum and facilities for instruction of a quarter of a century ago with those of the present.

"Dr. Marburg's influence on engineering was far-reaching and salutary. It was strongly felt in his work as a teacher, writer and executive throughout a wide and important circle of professional friends and acquaintances. It may truly be said that he supplied in himself, through his broad contact with Engineering, a bond between his students and the professional life which they sought to enter. Though not himself a practicing engineer, he showed in his instruction the fullest appreciation of the value of practical illustration and acquaintance with business procedure. Through patient and sound advice he endeavored at all times to instil into the minds and hearts of his students a high regard for the dignity and worth of their chosen profession. The high standard of professional ethics which he set for them was but the expression of principles which he consistently observed throughout his professional life.

"Dr. Marburg fully recognized and accepted the opportunities and obligations of his position as a teacher in a great institution of learning. With him teaching was not principally an occupation with a livelihood as its object, but a profession of the highest order which he knew to be far-reaching in its influence on the economic and social fabric of the country, worthy of that patient and devoted effort which he always bestowed upon it. His success as a teacher is unquestioned, and followed naturally from the possession of those qualities which secure the respect, confidence and interest of students. He had to an unusual extent the faculty of divesting a subject of difficulties by exposing, through familiar and often homely illustrations, the fundamental thought involved and by arranging related matters with due regard to their importance. Recitations never lagged, were never tedious or unprofitable under the vitalizing influence of his strong nature. He felt the intellectual pulse of his classes and was quick to detect lack of comprehension. It was never too much trouble to extend instruction beyond the class-room to the earnest student in need of assistance.

"A strict disciplinarian in all things essential, Professor Marburg still had the good will if not the affection of his students, based on his absolute fairness and justice and on the evident desire to apply the penalty for misdoing more as a corrective and deterrent than as a punishment. Since his death not a few letters have been received from his

former students attributing much of their success to his instruction and influence as a man and expressing heartfelt regret that they had postponed the acknowledgment of their debt to him in person until too late."

The following is a copy of the resolutions of the Faculty of the Towne Scientific School of the University of Pennsylvania upon his death:

"EDGAR MARBURG, Sc. D., L. L. D.,
"Professor of Civil Engineering, 1892-1918.
"Deceased June 27th, 1918.

"Moved by a profound sense of loss, this Faculty deems it a privilege to here record its estimate of the character and attainments of a colleague, who, although removed by death, has left an abiding influence for good through the vitality and idealism of his life work.

"The career of Edgar Marburg, shortened by its very excess of self-giving, nevertheless had long yielded him a distinguished position among engineers and educators. This was due to exceptional force of character and intellectual endowment which, both in preparatory training and professional and teaching activities, placed everything he did on a high plane. His work was marked by clarity and readiness of insight, grasp of essentials and thoroughness of method, and was inspired by high principles and a rugged honesty of view and purpose.

"Efficiency of so high an order, addressed to essentials, through more than thirty years of incessant activity, has made the life work of Edgar Marburg a contribution of positive constructive value to the welfare of the community. In two channels particularly has this been demonstrated; the more widely known that of the American Society for Testing Materials, whose great service to the Engineering and industrial worlds is due, more than to any other single influence, to his labors. The other channel, invisible but potent, is that of the careers of many students who have passed under his influence, carrying away as fundamental to their action his ideals of professional conduct.

"It has been well said of him that he had a constant desire to know the truth and be guided by it; possibly this best explains his life and the reason why we, his colleagues, are moved to add to this summary of his achievements an expression of profound respect for his character and of affectionate regard for the underlying warmth and kindliness of his nature.

"To the family of Professor Marburg we offer our sincere sympathy in their bereavement, and while knowing that no mere words can lessen its magnitude, we yet venture to hope that consolation may be found in the knowledge that his life, although prematurely ended, has been rich in a usefulness not to be measured by length of days.

"*Resolved:* That the foregoing be adopted as the sense of this Faculty, and spread upon the minutes, and that copies be addressed to the family of Professor Marburg and the professional organizations of which he was a member."

In 1906 a new building at the University of Pennsylvania was dedicated for the use of the Departments of Civil, Mechanical and Electrical Engineering, embodying at that time all of the latest approved facilities and apparatus required by technical schools of the highest

grade. The planning and detail designing of this building was entrusted to Dr. Henry W. Spangler, at that time Professor of Mechanical and Electrical Engineering, and Dr. Marburg, who were given *carte blanche* by the Trustees. The product of their joint work will always be a monument to each. At the time of the dedication of the building Honorary Degrees of Doctor of Science were conferred upon Professors Marburg and Spangler.

Almost immediately after settling in Philadelphia, Dr. Marburg became connected with the Engineers' Club of Philadelphia and was its President in 1900. His work in this connection is well set forth by George S. Webster, M. Am. Soc. C. E., as follows:

"In the death of Edgar Marburg, the Engineers' Club of Philadelphia lost one of its most valued members; one who always took an active interest in its welfare.

"He was elected a member of the Club October 21st, 1893, and was chosen one of the Directors in 1895 and 1896; and ably served as President during the year 1900. He was Chairman of the Committee on Public Relations in 1912, and from March 21st, 1908 until the time of his death was one of the Trustees of the Bond Redemption Fund.

"Dr. Marburg was deeply interested in the several movements of the Club to enlarge its sphere of usefulness, to increase its membership and to bring it into closer relations with other technical societies; and he contributed in no small measure to the accomplishment of the splendid results which followed these efforts.

"Earnestness of purpose and high ideals were among his characteristics, impelling him to urge the most exalted standards of ethics for the Engineering Profession, and to recommend as a duty a more active participation by Engineers in public affairs, in order that they might render greater service to the community.

"He was a man of strong convictions, and while energetically presenting his views, was very considerate of the views of others, and heartily united with them in doing that which seemed to be best for the interest of all.

"He took a leading part in making constructive suggestions at the hearings held in October, 1914, before the Engineers' Commission, appointed by the Governor of the State of Pennsylvania to investigate and report upon the advisability of licensing engineers. The clear and logical way in which arguments were presented by him at these hearings exerted a large influence upon the Commission in reaching its decision not to recommend the enactment of a License Law at that time.

"Dr. Marburg was a man of scholarly attainments, and made numerous valuable and interesting contributions to technical literature. He possessed characteristics which made him distinctive among his associates and marked him as a forceful man with original and striking ideas and quick to put them into effect. In fact, it was his unbounded energy coupled with the deep knowledge of the subjects he took hold of—and his resourcefulness in solving the problems which arose therewith—which made of him a distinguished and representative member in his profession.

"His sterling qualities and unquestioned honesty of purpose gained for him the respect and admiration of all his associates, and his death is mourned as a great personal and professional loss not only by the members of the Engineers' Club of Philadelphia but by all who had the privilege of his acquaintance."

At a meeting of the Board of Directors of the Engineers' Club held July 8th, 1918, the following resolution was adopted:

"The Engineers' Club of Philadelphia learns with profound sorrow of the death, on June 27th, 1918, of its beloved fellow-member and Past-President, Edgar Marburg. The Engineers' Club has, in the death of Edgar Marburg, lost one of its most valued members, whose loyal service has left a deep impression on the history and development of the Club, whose scholarship has earned for him an international reputation and whose personal influence has helped the members in their work and professional advancement.

"The Engineers' Club extends to his family its warmest sympathy in their bereavement and sorrow; and as an acknowledgment of his loyalty, brilliant leadership, kindly sympathy, ready helpfulness and professional ability, it is directed that this resolution of condolence and regret be published in the Journal of the Engineers' Club, together with a sketch of his life."

Possibly the greatest work in which he was ever engaged was his connection with the American Society for Testing Materials. In 1898 he joined the American Section of the International Association for Testing Materials and helped to organize the American Section of that Association. In 1902, when it became evident that a real leader would have to be found to vitalize the Society, the American Section turned to him. A concise statement of this part of his work is given in the following minute on his death which was passed at the October meeting of the Executive Committee of the Society, in 1918:

"In the death of Edgar Marburg, which occurred on June 27th, 1918, the American Society for Testing Materials has suffered the irreparable loss of one of its most eminent and distinguished members; its executive officer since its incorporation; a leader in engineering thought and education and in the field of testing materials.

"He was one of a small group which, in 1898, organized the American Section of the International Association for Testing Materials. In 1902 he was appointed acting secretary of the Section. He at once prepared for the Executive Committee a clear, comprehensive statement of the purposes of a testing society, as he conceived them, which led to the incorporation of the Society as an independent body. He was elected Secretary and Treasurer of the new society, and to him was entrusted the executive direction of its affairs. From then till his death, a period of sixteen years, he worked assiduously for the success and advancement of the Society. He devoted much time and thought to the work of its technical committees and the standardization of specifications and methods of tests of the materials of engineering, and he shaped the policy under which these essential activities of the

Society are conducted. The marked success which has attended the work and growth of the Society, and the interest and pleasures of its annual meetings, have been due in a large part to his tireless and painstaking efforts. To his labors he brought great executive and organizing ability, excellent judgment, a clear grasp of the many and varied problems which confronted him, a sympathetic understanding of humanity, tremendous enthusiasm and zeal, and thoroughness in everything he undertook. His high ideals were reflected in every word and act. He was ever zealous of the good name of the Society and sought throughout his leadership to extend its usefulness in every proper field.

"To the officers and members of the Executive Committee, who were privileged to work intimately with him, his death brings a deep sense of personal loss and grief. His high integrity, his rugged honesty, his open-mindedness, and his evident sincerity of purpose, endeared him to his associates, and commanded their admiration, respect and devotion.

"The character and personality of Edgar Marburg have indelibly impressed themselves upon the American Society for Testing Materials —an inspiration to the Society for all time."

Past-President A. A. Stevenson of the American Society for Testing Materials has kindly prepared the following statement which shows many of the characteristics of the man:

"No doubt the members at large of the American Society for Testing Materials appreciate, in a certain measure, how much Dr. Marburg's connection with the Society had to do with its success. Those of us who as officers of the Society and members of the Executive Committee during Dr. Marburg's tenure of office, had the privilege of working with him, can alone have a full realization of the extent to which his character as a man, with his ideas and ideals, independent of his work, had to do with the growth of the Society in influence and in numbers.

"Any one working with the Doctor could not but have the greatest admiration for him. While at times one might have differed with him, there was never a question as to his motives, or a thought that he was prompted by any other motive than what, in his mind, was best for the Society. Dr. Marburg had at all times the interest of the Society at heart, and no one could have been more jealous of its good name. He would make any sacrifice and go to any length in working to advance its interest. His very enthusiasm and devotion led to overwork, and I have no doubt that this, in connection with his work at the University, was largely one of the causes that led to his untimely death in the prime of life. With it all, one could not but be impressed by the great modesty of the man. He was most bitterly opposed to anything that might seem like self aggrandizement. It was the Society he thought of, and not himself. His desire was to see results; his greatest satisfaction in work accomplished.

"As an officer and member of the Executive Committee I worked with Dr. Marburg seven years; saw a great deal of him, and had many conferences concerning the work and the future of the Society. The official relationship developed into a warm personal friendship that is,

and always will be, one of my most cherished memories. His 'Old man, how are you?' over the telephone or when met, is sadly missed.

"To me the most outstanding trait in Dr. Marburg's character was his sterling honesty. He was honest in his ideals, in his work, and in his life. What more fitting tribute could be paid to a man?"

At the Annual Meeting of the American Society for Testing Materials, held in Atlantic City in June, 1919, a special Session was held in his honor and addresses were made as follows:

Introductory Remarks..............President G. H. Clamer
Contributions to Engineering...........Mr. John M. Goodell
His Early Activities in the Society.....Mr. Robert W. Lesley
His More Recent Service in the Society....Prof. A. N. Talbot
A Personal Tribute................Captain Robert W. Hunt

The addresses in full can be found in the *Proceedings* of the American Society for Testing Materials for 1919.

In 1919 the American Society for Testing Materials established an Edgar Marburg Memorial Scholarship in the University of Pennsylvania, to be awarded by the University to a student in the Department of Civil Engineering. The fund for this scholarship ($5 000) was raised by subscription from the members of the Society.

With reference to the above *Engineering News-Record* commented editorially as follows:

"No more appropriate form of memorial to the memory of Edgar Marburg than the proposed permanent scholarship in his own institution, the University of Pennsylvania, to which he gave practically the whole of his working life, could be conceived. The plan by which the American Society for Testing Materials is collecting the fund for a memorial scholarship, is worthy of the highest commendation. This form of recognition would appeal to Dr. Marburg himself, because his whole heart went out in the true teaching instinct to develop young engineers into men worthy of the great profession to which he gave his life. It is to be hoped that the future students who will benefit by this scholarship may fully appreciate the honor and repay it a hundred fold by their later contributions to engineering progress. It is unfortunate that only members of the A. S. T. M. have been asked to subscribe. There is no doubt whatever that thousands of other engineers the country over would be glad to add their tribute to a man who had been their inspiration and guide either in the days of their early training or in their engineering experience."

He acted as Consulting Engineer at various times, notably in the preparation of the design for the Rock Creek bridge on the line of Massachusetts Avenue, Washington, D. C., under commission for the Corps of Engineers, U. S. A.

In 1904 he was elected Lecturer on Structural Engineering at the Franklin Institute, and he was Past-Chairman of its Committee on

Science and the Arts. He was also Secretary of the American Society for the Promotion of Engineering Education, and Past-President of the honorary society, Sigma Xi.

In addition to a number of papers for the American Society for Testing Materials, his best known contribution to engineering literature is his work on "Framed Structures and Girders—Theory and Practice. Volume 1". This was the first of an unfinished series of three volumes covering the field of structural steel design and erection.

In 1896 he presented a paper before the Engineers' Club of Philadelphia, on "Cantilever Bridges". This notable paper was used in his classes from the time of its presentation.

He also contributed papers to the American Society for the Promotion of Engineering Education. In 1914 he was honored by Franklin and Marshall College with the degree of Doctor of Laws and Letters.

He was married to Miss Fannie Dulany Moncure of Shreveport, La., at Shreveport, on August 14th, 1893. Mrs. Marburg and their four children, Edgar, Mrs. Samuel T. Ziegler, Clara and Anita survive him.

He was elected a Member of the American Society of Civil Engineers on October 6th, 1897.

CARL UHLIG, M. Am. Soc. C. E.*

DIED MAY 4TH, 1919.

Carl Uhlig was born in Chemnitz, Saxony, on December 31st, 1846. He was educated in Saxon schools and was graduated from the Polytechnic School in Dresden in 1867.

He came to the United States in 1868 and shortly afterward entered the service of the United States Coast and Geodetic Survey as Aid, having been engaged in work at various points on the coast of California, principally at San Pedro and Crescent City.

In 1876, Mr. Uhlig entered the employ of the Board of State Harbor Commissioners in San Francisco as Chief Draftsman, being later appointed Assistant Engineer, and remained in that position continuously for 43 years, until his death. During that time he was connected with the design of the numerous bulkhead wharves, piers, ferry slips, sea walls and other water-front structures built by the Board, and accumulated a fund of information bearing on the hydrographic and topographic conditions of the San Francisco frontage that was particularly valuable and made of him an authority on this subject, consulted by all who contemplated any engineering work in that vicinity.

* Memoir prepared by the following Committee of the San Francisco Association of Members of the American Society of Civil Engineers: Frank G. White, Howard C. Holmes, and Jerome Newman, Members, Am. Soc. C. E.

Mr. Uhlig was a man of high character, scrupulous integrity, and amiable personal qualities. He had a wide circle of friends in all walks of life and was regarded with feelings of esteem and affection by all who enjoyed the privilege of his friendship. The best tribute to his ability as an engineer is the fact of his having been retained in his position by his employers, the Board of State Harbor Commissioners, during the political vicissitudes of over 40 years; though the personnel of the Board was changed repeatedly, his thorough knowledge of conditions was considered invaluable and no attempt was made to replace him.

Mr. Uhlig never married, and is survived by two sisters. He had been in failing health for some years, and his death from heart disease on May 4th, 1919, was not entirely unexpected.

Mr. Uhlig was elected a Member of the American Society of Civil Engineers on October 7th, 1903.

BERNT BERGER, Assoc. M. Am. Soc. C. E.*

Died January 16th, 1919.

Bernt Berger was born in Drammen, Norway, on July 12th, 1866. He was graduated from the High School there in 1881, and from the Mechanical Engineering Branch of the Technical Institute of Trondhjem, Norway, in 1885.

After one year's employment in the City Engineer's Office in Drammen, Mr. Berger came to New York City, arriving on September 14th, 1886, and almost immediately entered the employment of the late Theodore Cooper, M. Am. Soc. C. E., Consulting Bridge Engineer, with whom he remained until the latter retired from business in 1908, when Mr. Berger succeeded to his very important consulting practice, in addition to what he had individually developed along similar lines.

Mr. Berger's great accuracy and careful methods of investigation and sound treatment of technical subjects won for him the complete confidence of Mr. Cooper and his clients, and he developed a great capacity for handling successfully difficult structural problems and had responsible charge of many reports, investigations, and designs. He specialized largely in important and long-span steel bridges, general steel construction, masonry and concrete arch spans, reinforced concrete construction, and substructure work.

Among the important structures with which Mr. Berger was connected may be mentioned the Quebec Bridge, the New York Public Library Building, the New York City Elevated Railroad structures, and

* Memoir prepared by Frank W. Skinner, M. Am. Soc. C. E.

important bridges for many railroad companies, including some in South America and in Japan. He also specialized in examinations and recommendations for the safety of existing structures and for difficult repair and reconstruction work that was of great value to the engineers, contractors, and architects who were his clients. He was associated with much of the recent New York City subway construction, having been retained to supervise the steelwork on several important sections.

Few of his clients failed to re-engage him whenever they had subsequent work in his field. He was employed frequently by the New York Edison Company and the Edison Electric Illuminating Company, of Brooklyn, The Dayton Light and Power Co., The Utica Gas and Electric Co., The Underpinning and Foundation Company, The U. S. Realty and Improvement Company, The Cranford Company, of Brooklyn, Holbrook, Cabot and Rollins, The Pennsylvania Shipbuilding Company, The New York Tunnel Company, and many other companies and individuals were included among his clients.

Mr. Berger was a Past-President of the Brooklyn Engineers' Club, a member of the Engineers' Club of New York, the American Society for Testing Materials, and of the American Concrete Institute. He was also the Permanent Chairman of the Trondhjem Technical Club and a member of the Crescent Athletic Club, of Brooklyn, and, for many years, one of the Board of Managers and Treasurer of the Norwegian Lutheran Deaconesses Home and Hospital, a Trustee of the Norwegian Sailors' Church, Director of the Norwegian Society, and Secretary of the Hospital Saturday and Sunday Association, all of Brooklyn, N. Y.

Mr. Berger was fond of outdoor life and sports, including golf, sailing, bicycling, and skeeing. Although of a studious disposition, with cultivated literary taste, he found time for much social relaxation with a large circle of warm friends who claimed all his leisure moments. He was especially devoted to the interests of all his fellow engineers and never failed to lend a kindly hand and to have an encouraging word for the younger members of the Profession, many of whom he established in positions among his numerous friends and clients. His purse was always open to the necessities of struggling young engineers or students, and he befriended many of them, especially those who had arrived from abroad with only a few friends and no experience in this country. Mr. Berger lived in Brooklyn for twenty-five years; he was never married, and is survived by one brother in New York City and two brothers in Norway.

By his death on January 16th, 1919, the Society has been deprived of an able, vigorous member, always ready to devote his utmost efforts and zeal for its benefit; the Profession of Civil Engineering has lost a scholar, designer, and constructor; his clients have been deprived of notable skill and practical ability and unusually reliable services that

were always rendered with the utmost care and thoroughness on every occasion; while his numerous friends can never forget the genial comradeship and hearty affection that endeared him beyond the ordinary to all with whom he came in close and sympathetic touch.

Mr. Berger was elected an Associate Member of the American Society of Civil Engineers on April 5th, 1893.

WILLIAM BLAIR BOVYER, Assoc. M. Am. Soc. C. E.*

Died July 20th, 1918.

William Blair Bovyer, the son of Edward Bovyer and Anna (Kearse) Bovyer, was born in San Francisco, Cal., on March 16th, 1887. He received his elementary education in the public schools of San Francisco and attended the Mission High School of that city, from which he was graduated in 1905 and entered the University of California with the intention of studying law. Mr. Bovyer soon found, however, that engineering had a stronger appeal for him. He left the study of law and began a course in Civil Engineering from which he was graduated in 1910 with the degree of B. S.

For the first two years following his graduation, Mr. Bovyer worked successively for the Pacific Rolling Mill Company, Dyer Brothers Iron Works, the United Railroads of San Francisco, Selby Smelting Co., and Maurice C. Couchet, M. Am. Soc. C. E., Consulting Engineer.

In 1912, he became connected with the City Engineer's Office of San Francisco, where he attained the grade of Assistant Engineer. He worked on most of the city's important engineering works of that period and made many of the drawings and designs of the tunnels, sewer systems, water-works, and other structures constructed by the city.

In 1917, Mr. Bovyer was granted a leave of absence from the City Engineer's office and became connected with the work of the Board of State Harbor Commissioners of San Francisco, where he was employed until his death. During this time he was engaged in the design of all classes of water-front structures such as piers, wharves, buildings, etc.

Mr. Bovyer was a man who always put his best efforts into his work, and the record which he made proves that he made no mistake in his choice of a profession. He was a man of pleasing personality and in all of his personal and professional relations his outstanding characteristics were kindness and complete sincerity and frankness. His

* Memoir prepared by the following Committee of the San Francisco Association of Members of the American Society of Civil Engineers: Frank G. White, M. Am. Soc. C. E., and Leon H. Nishkian, Assoc. M. Am. Soc. C. E.

joyous outlook on life and its many problems always acted as an inspiration and a tonic to all who came in contact with him. His genial nature will be long remembered by his friends.

In August, 1915, Mr. Bovyer was married to Miss Cora Niedor, who, with two daughters, Ruth, age four, and Patricia, age one, survive him.

Mr. Bovyer was elected a Junior of the American Society of Civil Engineers on October 1st, 1913, and an Associate Member on September 12th, 1916.

ROBERT EDWARD DAKIN, Assoc. M. Am. Soc. C. E.*

DIED DECEMBER 15TH, 1918.

Robert Edward Dakin was born at Gaylordsville, Conn., on July 2d, 1888. He was graduated from the New Milford High School in 1906, and three years later received the degree of Bachelor of Science (Civil Engineer) from the Sheffield Scientific School of Yale University. In the fall of 1909, following his graduation from Yale, Mr. Dakin entered the service of the New York, New Haven, and Hartford Railroad, in charge of electric railway construction.

Mr. Charles S. Mellen, then President of the New Haven Railroad, in an endeavor to carry out his great plan of a unified transportation system for New England, had acquired for feeders to the steam and water lines an extensive system of trolleys, and, until April, 1917, Mr. Dakin was engaged in the reconstruction of many of these properties, the construction of extensions and connecting links, and, in the latter half of the period, in the preparation of maps, land records, mileage and tax reports, appraisals, and other forms of data, for submission to the various commissions having jurisdiction or interest in various features of the property.

In detail may be mentioned surveys and estimates for the construction of about 20 miles of new trolley line and for the relocation of several smaller sections; the surveys and estimates for an 8-mile, wood pole, transmission line and for an 11-mile, steel tower line, including the construction of the former; the construction of car-houses at Derby and New Haven; of freight-houses at Ansonia, Naugatuck, New Haven, and Waterbury; the enlargement of the Bridgeport steam station; the improvements and additions to the Bulls Bridge hydro-electric plant, the latter work, although not of great magnitude, called for a high degree of ability and ingenuity, as the new penstock and stand-pipe with the concrete pier in the tail-race, and the new head and fore-bay gates, had to be installed with practically no interference with

* Memoir prepared by Charles Rufus Harte, M. Am. Soc. C. E.

the operation of the plant, the operating head of 108 ft. making the tail-race work which came just at the ends of the draft tubes, particularly difficult; the construction of a reinforced highway bridge over the penstocks and the widening of the canal for several hundred feet, also had their difficulties, but to a less degree. Of Mr. Dakin's office work may be mentioned the design and estimates for a 4 000-kw., 40-ft. head, hydro-electric plant, and appraisals of the power plants, car-houses, and other buildings and structures of the trolley line between New London and the Massachusetts State Line, of the entire property of the Westport Water Company, and of many smaller groups of trolley properties of The Connecticut Company.

Successively filling positions of steadily increasing responsibility, Mr. Dakin's work came to the attention of the interests which had just purchased the Housatonic Power Company for the New York, New Haven, and Hartford Railroad, and, in April, 1917, he went with them, successfully handling the purchase of much right of way and the adjustment of changes of highways and bridges, necessary for the construction of a 75-ft. head, 24 000-kw. capacity, hydro-electric plant on the Housatonic River, at Stevenson, Conn. Later, when construction started, Mr. Dakin was transferred to the J. A. P. Crisfield Contracting Company, and, as Assistant Engineer, had charge of all surveys, maps, and highway changes, the latter involving a number of country roads and some State highways. In connection with the latter, Mr. Dakin constructed over the Pomperaug River a reinforced concrete cantilever bridge of arch form, with a central span of 90 ft., and semi-arches 45 ft. long on either side, the design being the joint work of Mr. Dakin and R. L. Saunders, Deputy State Highway Commissioner of Connecticut. The pool, 10 miles in length, fills a narrow valley with steep hills and deep intersecting ravines on each side, making surveys difficult and the determination of the economic relocation of the disturbed highways a problem calling for engineering ability of high order, while the natural difficulties of the field work were greatly increased by the fact that most of it had to be done during the severe winter of 1917-18.

Mr. Dakin was completing this work, and had organized the forces and was directing the surveys of other power and storage projects, when, after a very brief illness, he died at Danbury, Conn., on December 15th, 1918, a victim of the influenza epidemic of that winter. On September 13th, 1913, he was married to Marion Evans, of Gaylordsville, Conn., who, with a son, Theodore, born on November 11th, 1916, survives him. Another son, Edward, born on January 28th, 1918, and Mrs. Dakin's mother died within a few hours of Mr. Dakin.

"Rob" Dakin, as he was best known to his friends, was a man of engaging personality, combining to a rare degree technical ability,

executive capacity, and a "sunshiny" disposition next to impossible to ruffle. Although cut down at little more than the beginning of a career of great promise, he left no small monument in good work well done, and in the hearts of his friends an undying memory.

Mr. Dakin was elected a Junior of the American Society of Civil Engineers on December 2d, 1914, and an Associate Member on January 15th, 1917.

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OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLVI—No. 3

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

March, 1920

Published by the American Society of Civil Engineers at its Headquarters, 33 West Thirty-ninth Street, New York, the Fourth Wednesday of each Month, except June and July.

Entered as Second-Class Matter, December 14th, 1896, at the Post Office at New York, N. Y., under the Act of March 3d, 1879.
Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3d, 1917, authorized on July 5th, 1918.
Subscription, $8 per annum.

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Edited by the Secretary, under the direction of the Committee on Publications.

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The Reading Room of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, New Year's Day, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 6 P. M.

HEADQUARTERS OF THE SOCIETY—33 WEST THIRTY-NINTH STREET, NEW YORK.

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Vol. XLVI. MARCH, 1920. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

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MINUTES OF MEETINGS OF THE SOCIETY

February 18th, 1920.—The meeting was called to order at 8.30 P. M.; President Arthur P. Davis in the chair; Herbert S. Crocker, Vice-President, acting as Secretary; and present, also, 226 members and guests.

The President announced an address by M. O. Leighton, M. Am. Soc. C. E., to be delivered the following evening in the Auditorium of the Engineering Societies Building on the subject "The Engineer as a Citizen—Are You a Real Citizen, or Do You Just Live Here?"

The speaker of the evening, Thomas C. Desmond, Assoc. M. Am. Soc. C. E., was introduced by President Davis, and addressed the meeting informally on the subject "Human Elements in Modern Industrial Management."* The talk was illustrated by many views of the work done at the Newburgh Shipyards, Inc., of which Mr. Desmond is President. Evidence of the great interest aroused in the address, was shown

* See page 328.

by the many questions asked at its conclusion, giving Mr. Desmond further opportunity to explain fully the details of the radical methods adopted in his management of the labor situation at the Newburgh Yards.

The Secretary announced the following deaths:

Theodore Boyden Ford, of Bridgeport, Conn., elected Member, December 6th, 1905; died February 2d, 1920.

George Sullivan Morrill, of Penacook, N. H., elected Member, March 2d, 1887; died February 9th, 1920.

Robert Winthrop Pratt, of Cleveland, Ohio, elected Member, June 6th, 1911; died February 2d, 1920.

Edwin Foster Smith, of Philadelphia, Pa., elected Member, June 5th, 1895; died January 26th, 1920.

Willis Benton Wright, of New Orleans, La., elected Member, November 3d, 1897; died November 16th, 1919.

Ray Rolph Palmer, of Eagle Rock, Cal., elected Associate Member, October 10th, 1916; died December 25th, 1919.

Adjourned.

March 3d, 1920.—The meeting was called to order at 8.30 P. M.; Vice-President Herbert S. Crocker in the chair and acting as Secretary; and present, also, 169 members and guests.

In the absence of the author, a paper by Frank G. Jonah, M. Am. Soc. C. E., formerly Lt.-Colonel, Engineers, U. S. A., entitled "The 'Light Railways' of the Battle Front in France", was read by J. P. J. Williams, Assoc. M. Am. Soc. C. E. The subject was discussed by H. F. Dunham, M. Am. Soc C. E., who illustrated his remarks by motion pictures, and Messrs. F. W. Perry, F. A. Molitor, T. Kennard Thomson, F. A. Snyder, M. E. Pumphrey, H. L. Hoyt, C. Raymond Hulsart, and W. B. Poland.

Written discussions were received from Messrs. William Wren Hay, F. W. Green, W. J. Wilgus, and Maj.-Gen. William M. Black, U. S. A. (*Retired*), but, on account of the lateness of the hour, were not read.

The Chairman announced the following deaths:

Charles Emerson Gregory, of East Orange, N. J., elected Junior, October 6th, 1896; Associate Member, March 6th, 1901; Member, June 19th, 1918; died February 21st, 1920.

Thomas Hooker Loomis, of Steubenville, Ohio, elected Member, January 7th, 1903; died February 11th, 1920.

Alexander McClure Lupfer, of Portland, Ore., elected Member, November 1st, 1905; died February 3d, 1920.

Samuel Clarence Thompson, of New York City, elected Member, February 6th, 1889; died February 28th, 1920.

Adjourned.

OF THE BOARD OF DIRECTION

(Abstract)

March 9th, 1920.—The Board met at 11 P. M., immediately after the adjournment of the Membership Committee; President Davis in the chair; H. S. Crocker, Acting Secretary; and present, also, Messrs. Clark, Elwell, Greene, Hudson, Ketchum, Langthorn, Pegram, Tuttle, and Wagner.

Ballots for membership were canvassed resulting in the election of 17 Members, 55 Associate Members, 1 Associate, and 12 Juniors, and the transfer of 12 Juniors to the grade of Associate Member.

One Associate was transferred to the grade of Associate Member, and 24 Associate Members were transferred to the grade of Member.

A report from the Membership Committee was received and acted upon.

Adjourned.

HUMAN ELEMENTS IN MODERN INDUSTRIAL MANAGEMENT

Address by Thomas C. Desmond, Assoc. M. Am. Soc. C. E., at the Meeting of the Society, February 18th, 1920.

The following abstract of the informal address by Thomas C. Desmond, Assoc. M. Am. Soc. C. E., presented at the New York Meeting of the Society on February 18th, 1920, includes the points emphasized by the speaker in describing the methods used in the Newburgh Shipyards, Inc., of which he is President. This yard is located on the Hudson River about 60 miles above New York City, at a site particularly selected because of its beautiful view of Storm King Mountain, in the belief that attractive surroundings help to maintain a higher standard of personnel among the workers.

The shipyard is run as a truly open shop; a number of men belong to the union, but this is a matter of indifference to the management. If a union delegate wishes to talk over any grievance he is received with exactly the same consideration as any other worker, and no effort is made to discourage men from joining the union. The right of the men to bargain collectively was recognized from the beginning.

With the feeling that the 3 300 workers should act as one big union, a system of shop committees was adopted, three men from each trade being elected by the workers. This Shop Committee in turn elects an Executive Committee, with a Chairman and Secretary. It is a real functioning body, and representative along the lines of the best principles of democratic government. Up through that body come grievances of all kinds, many of which are there negotiated. Wages, conditions of labor, hours of employment, are considered. It is a system of collective bargaining. The men elect their representatives for six months, and it has worked out well. Many ideas come from that Shop Committee, and no man can truthfully say that he does not have any chance to get any ideas he may have straight up to the management.

The constant effort is to promote understanding between the workers and the management. The human problems which had to be faced were really more important than the technical problems. Starting at shipbuilding overnight, as it were, it was necessary to build up a war-time organization of 400 men when shipyards all over the country were confronted with the same problem of finding skilled workers. Before the war there were about 50 000 men working in American shipyards, and that force had to be expanded to 450 000 men—really some human problem.

Shipbuilding is a highly technical business, including many trades quite difficult for a man to pick up. It was first necessary to obtain a nucleus of competent men from other yards, 200 or 300 men, a num-

ber of them English or Scotch who had been thoroughly trained in the shipyards of England or Scotland. It was quite a problem to adjust the temperaments of those Englishmen and Scotchmen to American labor. It was recognized at once that it was necessary to cultivate good feeling, so a series of dinner parties and social occasions were arranged to bring the men together and a large part of the time of the higher executives was occupied bringing the foremen and superintendents into harmonious relationship and teamwork with each other, as well as with the workers. Picnics, local excursions, clambakes, etc., were effective in bringing the men together socially.

From the first, schools were conducted in the shipyard, and also night schools in Newburgh. Many Italians, Poles and Hungarians taken from New York construction work or from the West would work all day at the yard, and then go to school at night to learn the shipbuilding trades, where they were taught caulking, riveting, etc. After the work of ship construction had been started, one of the four ways was deliberately set aside for use as an experimental school, and every man who came into the yard had to go to the school ship before he was allowed to work with a regular gang.

It was necessary, therefore, to have foremen for the school ship who had teaching ability as well as sympathy with the men. To develop this teaching ability a course was given on how to teach, and thus a corps of about fifteen instructors was developed which inculcated a great spirit of helpfulness in the yard. This seemed like an obvious necessity in order to train new men and help to expand 50 000 skilled workers into the 450 000 required. Yet this schooling system was not applied generally elsewhere for some time. Its use made unnecessary the too common practice of stealing men from other shipyards. The men gained self-respect, and the ambition to go on and do things. They became mechanics instead of laborers.

Men who had never been inside a shipyard, such as farm-hands or grocery store clerks were trained as first-class riveters; in fact it was found that better results were obtained by training green men thoroughly than by taking on structural steel workers who were not familiar with the kind of water-tight riveting necessary in ship construction. The men are paid while they are learning.

Classes in English and American history were attended three nights per week, and much enthusiasm was manifested. About six months after these courses had been organized, it was announced that no orders whatever should be given in the yard in any language but English. Six months ago a rule was made that after three months no man would be allowed to work in the yard who was not an American citizen or who had not at least taken out his first papers. There is not a man on the pay-roll to-day who is not an American citizen or on the way to become one.

As an illustration of the spirit in the yard, the management during the recent epidemic of influenza was able to enforce an order that every man should have his nose sprayed daily with argerol. This is not only humanitarian, but it is also good business to keep the men well and not have them absent, breaking up gangs and stopping production. These little things help greatly. The men are contented and happy. The happier they are in their work, the better they like it, and the less is the labor turnover. It is estimated that it costs $50 every time a man is hired and fired in the Newburgh shipyard, and this is probably a conservative estimate.

The labor turnover, sometimes as high as 200% in some industries, has been kept very low by these methods and by furnishing opportunities for self-expression. Because the efficiency of modern industry very largely depends upon high production and specialization, the work is exceedingly monotonous, and the need for some outlets to develop self-respect is very great. At Newburgh, there has been encouraged, as a means to that end, the formation of different athletic teams, a band, social clubs, dances and picnics, always managed exclusively by the men.

The latter point is of great importance. Many industries have a so-called welfare director whose job it is to go out and promote good feeling and arrange these affairs. It is always harmful. Men do not want charity. They do not want their employers to interfere with their lives. They do not want to feel coddled. Particular care is taken therefore that no one actively connected with the management shall have anything to do with the control of these outside activities. No support, financially or otherwise, is given from "higher up".

There should be in every big industry something of what might be called a college spirit. The by-products of college life such as athletics and other outside activities are a great stimulus to enthusiasm and the right spirit. This same spirit can be developed in industries if the men are allowed to run things themselves. For example, when the baseball team wanted a ball park they themselves went out and borrowed $6 000 on a joint note, bought the lumber, and on their own time, with their friends, put up a grand stand, bleachers and fence, also graded and completed an excellent diamond. They run their own games and have in one season wiped out one-third of the debt.

In order to develop the democratic spirit in the industry, to introduce the human element and keep in sympathy with the men, one method used is Tuesday afternoon meetings of the officials with all the foremen and superintendents. The affairs of the Company are discussed freely; if a foreman has a criticism of some other foreman he is supposed to make it in open meeting, where he can be answered and the criticism defended. No "knocking" outside of these conferences is allowed. This has been found surprisingly effective in preventing the little cliques

and jealousies often found in large organizations. In addition, many excellent ideas come from these Tuesday conferences. The officials of the company become well known to the foremen and superintendents —a very great advantage, as these men form the link between the management and the workers.

The officials also go out among the men and make short addresses on such subjects as "How American Can Compete with English Shipyards", "Problems of Management", "Getting New Orders", etc., either at the lunch hour or at evening gatherings. Most trouble comes from lack of understanding and lack of acquaintance, and activities of the Shop Committee such as running Liberty Bond campaigns help greatly. While the principal duty of shop committees is to adjust serious grievances these come only once a year or so, and it is best to furnish other activities to keep them functioning.

On account of the housing shortage in Newburgh, the Company built 200 model houses, financed by borrowing money from the Government on mortgage. These houses are rented to both shipyard workers and outsiders, and a regular community club controls all the activities, the people taking turns watching the children at a common playground, etc., co-operating for their own happiness. In order to set a good standard of taste, one of the houses was completely furnished as a model, the department stores doing this gratis.

Thus, while using technical ingenuity to improve methods of production, and to raise the standard of construction as high as possible, according to the principles of sound engineering practice, at the same time endeavor is made never to forget that, after all, the human elements of production are far more important than the materials produced. Every line of industrial management might well remember that the humblest workman can have the same reactions as the rest of us to the principles of love and loyalty and human understanding.

In response to questions from the floor, Mr. Desmond elaborated some of the details of the work at Newburgh as follows: The 200 homes were built by a separate concern, the Newburgh Housing Corporation, the directors being business men of the town, dividends being limited to 5%, making rents about 25% lower than in the town; the homes cost about $5 000 apiece (single houses). There is no finer form of profit-sharing than piece work, but the rate once fixed for a given operation must never be lowered—the basis of payment must be changed if necessary. Contract work for parts of the ship is now being tried by letting to a gang on contract at a certain fixed sum. The average mechanic's wage is $6.40 for an 8-hour day and with a 48-hour week. More and more of a decentralization of industries, taking them from big cities and locating in small towns, is probable—materials cost no more, and labor is more contented.

ITEMS OF INTEREST

The Committee on Publications will be glad to receive communications of general interest to the Society, and will consider them for publication in *Proceedings* in "Items of Interest". This is intended to cover letters or suggestions from our membership covering matters which are not of a technical character. Such communications, however, must not be controversial or commercial.

NATIONAL SERVICE DEPARTMENT OF ENGINEERING COUNCIL

In response to frequent expressions of need, Engineering Council announces the establishment of a National Legislative and Departmental Information Service for engineers in all branches of the Profession. Information relative to engineering statistics, research, and construction, as well as of matters before Congress involving engineering considerations, will be furnished without charge by addressing M. O. Leighton, National Service Representative of Engineering Council, 502 McLachlen Building, Washington, D. C. This National Service Department of Engineering Council announces that its office at Washington is open to members of the Society at all times, and that accommodations can be had there at short notice for committee meetings of the Society, or of any organization in which the Society is interested, which may be held in Washington.

UNITED ENGINEERING SOCIETY

Extracts from Treasurer's Annual Report for Year Ending December 31st, 1919

The Surplus Account on December 31st, 1918, showed a balance of $5 533.43. This amount has been increased by the surplus from the operating accounts during the year of $9 557.28, making a total on December 31st, 1919, of $15 090.71. Of this amount $10 000 has been transferred to Depreciation and Renewal Fund, leaving a balance in Surplus Account of $5 090.71.

The Gross Operating Expenses for the year 1919 were $66 812.89, as compared with $66 505.57 for the year 1918, an increase of $307.32.

The funds available for the Library Board, and spent under its direction during the year, amounted to $23 876.64.

The funds available for Engineering Council, and spent under its direction during the year, amounted to $49 012.38, of which $940.07 remained unexpended.

The General Reserve Fund of $10 000 created by the Board of Trustees at a meeting held November 18th, 1914, to be available to take care of unforeseen fluctuations of income and outlay, has been preserved intact, there arising no calls on this fund during the year 1919.

The Depreciation and Renewal Fund at the beginning of the year 1919 amounted to $86 163.78. During the year this fund has been increased by the sum of $4 035.22 for interest earned by the investments for this fund and by $10 000 added from the surplus at the end of the year, making a total of $100 199.00 on December 31st, 1919.

In accordance with the authorization of the Board of Trustees, February 27th, 1919, the sum of $13 000 was invested in Government of United Kingdom of Great Britain and Ireland, 20-year bonds, 5½'s, due February, 1937, $5 000 being reinvestment of proceeds from Bethlehem Steel Co., 2-year Second Gold Notes matured February 15th, 1919, and $8 000 cash transferred from Surplus to the Depreciation and Renewal Fund.

The following summary shows the amounts of the funds held by the United Engineering Society as of December 31st, 1919:

Depreciation and Renewal Fund, December 31st, 1918	$86 163.78
Interest on invested funds during the year 1919	4 035.22
Transfer for the year 1919	10 000.00
Total	$100 199.00
General Reserve Fund	$10 000.00
Engineering Foundation Fund	303 374.80
Library Endowment Fund	102 559.70
Total	$516 133.50

Treasurer's Receipts and Payments for 1919

Receipts

Cash on hand January 1st, 1919		$12 869.60
From Founder and Associate Societies:		
For office, storage, halls, telephone, and miscellaneous	$76 984.08	
From Societies not in building:		
For Halls	5 727.70	
For Miscellaneous	658.57	
For Library	15 737.42	
For Library Service Bureau	17 740.65	
For Library Recataloging	5 624.99	
For Engineering Council	46 958.91	
Interest collected on Bonds and Deposits	9 640.75	
Interest collected on Engineering Foundation Bonds	15 324.24	
Maturing of $5 000 Bethlehem Steel Corporation Bonds	5 000.00	
From A. I. M. E., for Building addition	2 500.00	
From A. I. E. E., for Building addition	2 500.00	
		204 397.31
Grand Total		$217 266.91

Payments

To Engineering Foundation:		
Income from investments, less collection charges	$15 331.74	
For Govt. of Great Britain and Ireland Bonds	13 169.72	
For Building Operating Expenses	75 350.56	
For Library	24 209.99	
For Library Service Bureau	17 459.33	
For Library Recataloging	4 361.31	
For Engineering Council	49 630.48	
For A. S. M. E. Notes	5 000.00	
For A. S. M. E. Interest on Notes	108.49	
For Collect charges and exchanges	108.11	
Total Payments		204 729.73
Cash on hand December 31st, 1919		$12 537.18
Grand Total		$217,266.91

ASSETS AND LIABILITIES

December 31st, 1919.

Assets

Real Estate	$1 947 171.16
Investments, Engineering Foundation Fund	303 321.25
Investments, Library Endowment Fund	102 297.50
Investments, General Fund	93 894.72
Cash	12 637.18
Accrued interest receivable	2 806.88
Bills receivable	7 500.00
Accounts receivable	8 742.43
Advances to Library Board	2 602.36
	$2 480 973.48

Liabilities

Founders equity in property	$1 947 171.16
Due to General Reserve Fund	10 000.00
Due to Depreciation and Renewal Fund	100 199.00
Due to Engineering Foundation Fund	303 374.80
Due to Library Endowment	102 559.70
Bills payable	7 500.00
Library cataloging, unexpended balance	1 472.01
Library Service Bureau, unexpended balance	2 666.03
Engineering Council, unexpended balance	940.07
Surplus, December 31st, 1919	5 090.71
	$2 480 973.48

Annual Meeting of the United Engineering Society

The annual meeting of the Trustees of United Engineering Society was held in the Engineering Societies Building, New York City, on January 22d, 1920, with 13 present.

To Charles F. Rand, whose services for six years as Trustee and four years as President expired at this meeting, the American Society of Mechanical Engineers presented by the hand of Trustee McFarland, engrossed resolutions expressing appreciation of faithful and efficient labors for the Societies. The Trustees unanimously voted to President Rand their thanks for able and generous services to the United Engineering Society.

Upon nomination, the following officers were elected: President, J. Vipond Davies, M. Am. Soc. C. E.; First Vice-President, Walter M. McFarland; Second Vice-President, Calvert Townley; Secretary, Alfred D. Flinn, M. Am. Soc. C. E.; Treasurer, Joseph Struthers.

The following members were elected to the Engineering Foundation Board for terms of three years:

Charles F. Rand, as member at large; George H. Pegram, Past-President, Am. Soc. C. E., as Trustee representing the American Society of Civil Engineers; E. Gybbon Spilsbury as Trustee representing the American Society of Mechanical Engineers; and Samuel Sheldon, as Trustee representing the American Institute of Electrical Engineers.

On nomination, Clemens Herschel and Calvert Townley were re-elected as representatives of United Engineering Society on Engineering Council for terms of three years.

An invitation from The Authors Club, dated January 13th, 1920, to join with other organization in a memorial meeting to Andrew Carnegie Wednesday afternoon, February 4th, was read. It was voted that this invitation be accepted, and that the United Engineering Society participate.

In a communication dated January 12th, signed by Director Craver, the Library Board suggested modification of By-Laws 87 and 91 to provide for the annual election of a Vice-Chairman of that Board, and for meetings of the Executive Committee at the call of the Chairman instead of monthly, as now required. Resolutions prepared by Mr. Rand were proposed, and adopted as follows:

"*Resolved:* That there be and hereby is established the office of Vice-Chairman of the Library Board.

"*Resolved:* That in the absence of the Chairman of the Library Board, the Vice-Chairman of the Library Board shall discharge his duties.

"*Resolved:* That until further action of the Trustees, the Executive Committee of the Library Board shall hold meetings at the call of the Chairman, or in his absence, of the Vice-Chairman, of the Library Board.

Annual Report of Chairman of Engineering Foundation for Year Ending February, 1920

To the Engineering Foundation Board:

At the beginning of the year the Board was confronted with the necessity of adjusting its relations with the National Research Council, then in the process of reorganization on a peace basis.

Engineering Foundation had early given its support to the work of the Council, certain of its members were also members of the Council, and the Council had announced its purpose to create as a part of its permanent organization a Division of Engineering. It was apparent that in the absence of understandings to the contrary, the Division of Engineering might function in the same field as Engineering Foundation and select agencies through which to work, some of which were closely associated with Engineering Foundation. It was thought important, in the interest of research, to develop a procedure which would provide a definite field of action for both organizations and which would permit each to function in harmony with the other. A special committee gave careful attention to the various aspects of this problem. Conferences were held. The Committee finally recommended and the Board approved five proposals which may be briefly summarized as follows:

1.—That Engineering Foundation would work in close affiliation with the National Research Council.

2.—That Engineering Foundation would provide office space and contribute to the office expenses of the Engineering Division of the Council.

3.—That Engineering Foundation would approve a plan whereby a certain number of the members of Engineering Division of the Council would be selected from the membership of Engineering Foundation, and others from the membership of the Founder Societies.

4.—That Engineering Foundation would collaborate with the Engineering Division of the Council and would make such appropriations of funds to aid in such specific undertakings of the Division, as the Foundation may from time to time determine, and

5.—That Engineering Foundation would under certain conditions join with Engineering Division of the Council in joint publications.

These provisions have been in effect since their adoption by the Board on April 22d.

Progress has been made in the development of research under grants from the Foundation. Mr. Clemens Herschel has completed an elaborate series of tests upon hydraulic weirs and has completed a report which has recently been published by the American Society of Mechanical Engineers.* Dr. E. E. Southard's work on Mental Hygiene of

* *Mechanical Engineering*, February, 1920, p. 83.

Industry, which was started last year, was proceeding with satisfactory results until Dr. Southard's sudden death on February 8th. Publications with reference to both of these undertakings have appeared during the year.

Suggestions having been invited, the Division of Engineering recommended to the Foundation a study of the Fatigue Phenomena of Metals, in co-operation with the Engineering Experiment Station of the University of Illinois, the Engineering Division also participating. The accrual of unexpended balances of previous years permitted the Foundation to finance this project, notwithstanding the fact that the rate of expenditure involved was in excess of the Foundation's present rate of income. The program provided that the actual tests involved in this research are to be made by the University of Illinois; that the work is to be supervised on behalf of the Foundation by the Engineering Division; and that the major part of the funds needed are to be supplied by the Foundation. This work is already in progress.

The assistance of Engineering Foundation was sought during the summer by the Division of Engineering of the National Research Council in bringing about some elaboration of the Division's staff organization. The distinguished Chairman of the Division could no longer carry the routine of his office and asked to be relieved. The members of the Division believed that advantage would accrue to the Division by a retention of its pioneer leader as honorary chairman and by the appointment of a scientist of proven ability as a full-time active chairman. It asked whether Engineering Foundation could apply the funds necessary to such an arrangement. The Foundation Board agreed so to do and Dr. Henry M. Howe became the Honorary Chairman of the Division and Dr. Comfort A. Adams its active Chairman, an arrangement which supplied Engineering Division with leadership of a very unusual character.

The appropriation of funds to the Engineering Division necessary to the revised plan of organization just outlined, superimposed upon a liberal program of expenditure previously adopted for the support of its several researches, have been easily met during the present year. Assuming all expenditures to proceed at the rate they have been planned, deficits will accrue during the two years next succeeding. It is probable, however, that the rate of expenditures planned will not be realized, and that in the absence of further appropriations no actual deficits will occur. In order, however, to save the Foundation from possible embarrassment, a member of the Foundation Board, Mr. Edward Dean Adams, has generously guaranteed to protect the Board by contributing the sum of any deficit occurring in the discharge of obligations it has already assumed. The details of these several matters have been presented to the Board from time to time and constitute a part of its official record.

There have been many expressions of a desire during the year to enlarge the financial resources of Engineering Foundation. The policy to be followed in the solicitation of funds for this purpose has been a matter that has received the attention of a Special Committee of which Mr. Edward Dean Adams has been Chairman. A definite agreement has been reached with National Research Council, which should prevent conflict of interests in the solicitation of funds. There have been drafted for United Engineering Society as the holder of the endowment for Engineering Foundation: (1) Declaration of Trust, (2) Deed of Trust, (3) Form of Deed of Gift. The preparation of these documents is to be accepted as an important first step toward the solicitation of large sums for credit to the endowment fund of Engineering Foundation.

With these preparations of the Committee came a letter from Mr. Ambrose Swasey, which in full is as follows:

"December 19, 1919.

"Dr. W. F. M. Goss, Chairman,
Engineering Foundation,
New York.

"Dear Doctor Goss:

"I have always regarded my gifts to United Engineering Society for the support of Engineering Foundation, as an initial step in the development of an undertaking which would gain support from many sources and continue to develop year by year. As time has passed and as the service rendered by Engineering Foundation has increased, the reasonableness of such a view has become more and more apparent.

"The purpose of this note therefore is to say that I am prepared to add to the amounts I have already given for the benefit of Engineering Foundation, the sum of Two Hundred Thousand ($200,000) Dollars, and that I will do this as soon as gifts from other sources can be obtained which will equal the sum of the amounts which I have given and herein propose to give, namely, a half million dollars.

"While I am not disposed to complicate this proposal by the addition of any condition as to time, I assume that it will be the wish of the Foundation Board and of the United Engineering Society to make it possible for me to complete my gift under the terms of this note at as early a date as practicable, certainly during the calendar year of 1920.

Very truly yours,
(Signed) Ambrose Swasey."

In presenting this brief summary of a year's activity, your Chairman is impressed with the fact that Engineering Foundation is still in its formative state. In common with other undertakings new in character having relations, active and potential, of a very diverse sort, it has in its development been confronted by questions difficult of solution. There is nothing uncomplimentary in the statement that members of the Board have at times entertained widely different views with ref-

erence to matters of fundamental importance. In the settlement of such matters it has been deemed safe to follow the leadership of a clear majority. For example:

1.—For some years past there have been two widely divergent views in the Foundation Board concerning the means whereby the element of leadership should be supplied to the Board. A minority view has urged as a first requisite in the development of the purposes of the Board, the appointment of an Executive Secretary, notwithstanding the fact that the cost of such an officer and of his office would, for the time being, absorb practically all of the resources of the Foundation. A majority of the Board have been of the opinion that until the revenues of the Foundation could be enlarged, the Board should forego the advantages which would accrue from the presence of such an officer, and this view has been accepted as the view of the Board.

2.—In the development of Engineering Division of National Research Council, a majority of the Foundation Board have seen an agency which could serve the Foundation by supplying advisory leadership for the scientific aspects of its work, and by so doing make good the deficiency in the Board's own organization which a minority had been seeking to secure through the appointment of an Executive Secretary, and the Board has accepted the good offices of the Engineering Division.

3.—Engineering Foundation having accepted the leadership of Engineering Division, has subsequently consistently sought to make that leadership strong, and its direct grants to Engineering Division have been to this end. It is assumed that Foundation money invested in the organization of Engineering Division staff, is money spent for organized leadership for Engineering Foundation.

By these several procedures, the Foundation Board has secured superior leadership for its scientific activities, and it has developed co-operative relations where otherwise there might easily have been competition.

Respectfully submitted,
W. F. M. Goss,
Chairman.

ACTIVITIES OF ENGINEERING COUNCIL

Chairman's Report for Year Ending February, 1920

Items of special interest during the third year of Engineering Council's activities may be summarized as follows, according to the annual report of the Chairman, J. Parke Channing.

Council held five meetings; three in New York, one in Chicago in April, and one in Washington in June.

The total expenditures for the calendar year 1919 were $49 000, including $25 000 advanced by the Chairman for the expenses of the Washington office.

The Washington office was opened January 1st, 1919.

The American Society for Testing Materials completed qualifications as the fifth member society in February, and has since taken an active part in Council's work.

In April, Engineering Council called together in Chicago representatives of 74 technical organizations having 105 000 members, to discuss an effort to secure a National Department of Public Works. To conduct and finance this movement, there was created a body now known as the National Public Works Department Association. Branch organizations have been established in most of the States. Work has been directed chiefly from Council's Washington office. A bill was introduced into both houses of Congress. The Chamber of Commerce, U. S. A., was asked to submit the question to referendum, and appointed a special committee to investigate. Engineering Council appointed a committee to present arguments before the Chamber's committee. Meetings of these committees were held January 19th and 20th, 1920, in Washington, and the Chamber decided to issue the referendum. A second convention was held in Washington January 13th and 14th, 1920, at which 124 organizations were represented and good progress reported, except in collection of funds needed for support of the Association.

In September, Engineering Council became a member of the Chamber of Commerce, U. S. A.

Engineering Societies Employment Bureau, organized immediately after the Armistice, was maintained throughout the year. It registered 5 400 engineers, the majority of whom had been in Military or Naval Service, and aided a large proportion to find positions. It rendered service to both employers and employees without charge, but at a cost to the Founder Societies of more than $16 000. The Secretaries of the Founder Societies were the Board of Directors. At the end of the year, the Bureau was detached from Engineering Council by actions of the Founder Societies.

A Committee on Classification and Compensation of Engineers, created in March, worked in three sections dealing with engineers in the employment of (1) Federal Government, (2) Railways, (3) Cities and States. The committee has co-operated with the Congressional Commission on Reclassification of Salaries of Government Employees. A preliminary Report of the Federal Section was printed in pamphlet form by the Washington Academy of Sciences in November, 1919. In January, 1920, a report of the whole committee was published* in abbreviated form by the Founder Societies and the technical journals, espe-

* *Proceedings*, Am. Soc. C. E., January, 1920, p. 42.

cially *Engineering News-Record*. This report contained a standard classification of engineers (for purposes of compensation) and a suggested, tentative schedule of salaries for engineers in governmental employment.

To expedite completion of topographical maps of the United States, President Wilson, in response to a communication from Engineering Council, by Executive Order, constituted a Board of Surveys and Maps, of one representative each from the fourteen map-making agencies of the Government, and invited representatives of Engineering Council and engineering and scientific societies to co-operate. The new board set up a permanent organization on January 13th, 1920.*

The Committee on Licensing Engineers, after fourteen months' work, presented in December a valuable report accompanied by a "Recommended Uniform Registration Law, to regulate the practice of professional engineering, architecture and land surveying". This report has been published† and will be considered by Council at its February meeting.

Forty correspondents have been appointed in as many engineering centers in various parts of the country, and to them "Notes" and "Bulletins" about Council's work have been sent at frequent intervals from the New York and Washington offices.

The Fuel Conservation Committee continued co-operation with the Government, and recommended support of a Federal appropriation for a survey to determine the desirability of a super-power system in the industrial region extending from Boston to Washington.

The Water Conservation Committee appointed correspondents in 27 States, is seeking correspondents in other States, is collecting useful information, and is aiding the Maine Water Power Commission on questions of policy in response to a request from its Chief Engineer.

To the Reconstruction Commission of the State of New York, a special committee of engineers appointed by Council gave assistance in preparing a Report on Retrenchment and Reorganization in the State Government.

By public hearing, in January, 1919, Engineering Council aided the reinstatement of 350 engineers unfairly dismissed by the City of New York. It also assisted late in the year in securing better salaries for these and other engineers and in preventing a recurrence of last year's unfortunate conditions.

Council took part in organizing a National Board for Jurisdictional Awards in the Building Industries, and has a member thereon.

Council appointed three representatives to co-operate with equal numbers from the American Institute of Architects and the Associated

* *Proceedings*, Am. Soc. C. E., February, 1920, p. 261.

† *Proceedings*, Am. Soc. C. E., January, 1920, p. 27.

General Contractors of America, to determine a policy regarding "Payment for Estimating".

Late in 1919, and in January, 1920, committees were appointed on Types of Government Contracts, on Military Affairs, on Co-operation with the American Institute of Architects, and on Co-operation with the Association of Russian Engineers in America. In response to request, special assistance was given the Signal Corps, United States Army, in connection with bills before Congress.

On a National Budget System, Council presented testimony through four delegates sent to Washington on invitation of the Select Committee of the House of Representatives.

Council gave much assistance to the War Department Claims Board in securing technical experts to review reports on claims amounting to approximately $2 000 000 000.

During the past year it was impracticable for the Secretary to make more than a few visits to Engineering Societies, and then only to those relatively near New York. The combination of duties for United Engineering Society, Engineering Foundation and Council, together with lack of funds, prevented further visits. Nevertheless, many personal visits on behalf of Engineering Council have been made to groups of engineers from coast to coast by the Chairman; by Representatives Baker, Cooley, Hollis, Loweth, Moore, Skinner and Townley; by Chairman Leighton, of the National Service Committee; and by Secretaries Stoughton and Rice, of the Mining Engineers and the Mechanical Engineers, respectively. Several local societies, by letter or personal representative, have requested and received advice and other assistance from Council's office.

Engineering Council has continued to be handicapped by lack of adequate financing. At the suggestion, and with the approval of the member Societies, as an emergency measure, late in 1919, Council sent to 50 000 engineers throughout the country, an appeal for $30 000 to supply the minimum deficiency in requirements for 1920, over and above the amounts appropriated by the member Societies. Up to February 10th, 1920, 779 contributions have been received, totaling $5 530.90.

The Joint Conference Committee of the Founder Societies has recommended material changes in Council's form of organization. Council has approved the general principles of this report.

To determine questions as to future organization and financial support, Engineering Council invited the governing bodies of its member Societies to a joint conference in New York, January 23d, 1920. There were also invited the Joint Conference Committee and the Trustees of United Engineering Society.*

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* *Proceedings,* Am. Soc. C. E., February, 1920, p. 257.

Report of the Third Annual Meeting

The Third Annual Meeting of Engineering Council was called to order by Chairman J. Parke Channing, February 19th, 1920, in the Engineering Societies Building, New York City, with 21 present.

The Secretary reported that he had been duly notified of the election of new representatives. The representatives for the year ending at the Annual Meeting in February, 1921, are as follows:

American Society of Civil Engineers: Charles S. Churchill, Alex. C. Humphreys, Charles F. Loweth, Arthur N. Talbot, Joseph R. Worcester.

American Institute of Mining and Metallurgical Engineers: J. Parke Channing, Sidney J. Jennings, Edwin Ludlow, Philip N. Moore, F. T. Rubidge.*

American Society of Mechanical Engineers: L. P. Alford,* Charles Whiting Baker, Arthur M. Greene, Jr.,* Charles T. Main,* Fred J. Miller.*

American Institute of Electrical Engineers: Comfort A. Adams, Harold W. Buck, N. A. Carle, Charles S. Ruffner,* Charles E. Skinner.

American Society for Testing Materials: Albert Ladd Colby.

United Engineering Society: Clemens Herschel, I. E. Moultrop, B. B. Thayer, Calvert Townley.

The financial statement for the year showed a total expenditure of about $49 000, including the expenses of $25 000 for the National Service Committee which was guaranteed and personally paid in full by Chairman Channing. An unexpended balance of $940.07 was reported.

F. C. Shenehon, M. Am. Soc. C. E., presented a report from the Joint Committee on Co-operation with the American Institute of Architects stating that the Committee had discussed the report of the Committee on Licensing Engineers and the recommended Uniform Registration Law. The representatives of the Institute called attention to the fact that probably the model law created a wrong impression in its definition of a building and that it should be modified in this particular; they also stated that they believed this Uniform Registration Law should be submitted to the American Institute of Architects so that it might study the question as to whether it would be possible or advisable to recommend such a uniform law covering both engineers and architects. In this the representatives of Engineering Council agreed.

Upon the recommendation of this Joint Committee, action concerning the report of the Licensing Committee was deferred until the Institute of Architects shall have had opportunity for thorough consideration and for reporting its findings to Council. The Chairman was authorized to send copies of the Uniform Registration Law to States now considering the question of licensing.

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* Newly elected representatives.

Charles A. Terry's resignation as Chairman of the Patents Committee was accepted and Edwin J. Prindle was appointed in his stead. The Secretary was authorized to prepare a resolution expressing the approval of Engineering Council to the Nolan Bill and urging its passage. The following resolution was prepared and presented at a hearing before the Rules Committee of the House of Representatives:

"*Whereas,* Engineering Council has been informed by its Patent Committee that H. R. 11984, known as the Nolan Bill, consists essentially of provisions contained in bills previously endorsed by Council as the results of the labors of the Patents Committees of National Research Council and Engineering Council, and

"*Whereas,* it is believed that H. R. 11984, if enacted, will go a long distance towards correcting many present defects in the United States Patent System, be it

"*Resolved:* that Engineering Council approves in general the provisions of H. R. 11984, and urges its early passage."

Arthur P. Davis, President, Am. Soc. C. E., and Chairman of the Committee on Types of Government Contracts, presented a report by letter stating that the Committee had undertaken correspondence. especially with those having had experience with contract work for the Government, which had resulted in a large volume of replies containing criticism or suggestions of value, and that these were being digested for consideration by the Committee; also that a tabulation of the types of government contracts now in use by the various government bureaus had been undertaken, and that a great variety of practice, some of which might perhaps be standardized, was indicated.

M. O. Leighton, M. Am. Soc. C. E., Chairman of the National Service Committee, presented a report covering the activities of that Committee. In accordance with the recommendation of Chairman Leighton, the National Service Committee was discharged with thanks. and it was voted that the Washington office be continued and its name changed to "National Service Department of Engineering Council"; it was also voted that M. O. Leighton be continued as the Washington representative of Engineering Council, with the title "National Service Representative".

Col. J. J. Carty's resignation as a member of the Military Affairs Committee was accepted with regrets.

Mr. Leighton reported that by the terms of the Railroad Bill, the number of members of the Interstate Commerce Commission would be increased by two and that, with one existing vacancy, there would be three places to be filled. It was voted that a communication be sent to the President, suggesting that it would be desirable to appoint one or more engineers on the Interstate Commerce Commission; also that there be submitted to him a list of three names.

The following Committees were discharged with thanks: Americanization Committee; Advisory Committee to New York State Recon-

struction Commission; Publicity Committee; Publicity Methods Committee; Reconstruction Committee, and Advisory Committee to Bureau of Municipal Research.

A budget for a total of $53 000 for the year 1920 was adopted as a minimum. Of the $5 000 estimated for Committees and Contingencies, $3 000 was appropriated for the use of the Committee on Classification and Compensation of Engineers.

After the report of the Nominating Committee, the following officers were elected: Chairman, J. Parke Channing; First Vice-Chairman, H. W. Buck; Second Vice-Chairman, Charles S. Churchill, M. Am. Soc. C. E.; Secretary, Alfred D. Flinn, M. Am. Soc. C. E.; additional members of Executive Committee, Alex. C. Humphreys, M. Am. Soc. C. E., Charles Whiting Baker, and Philip N. Moore.

Military Affairs Committee

Under date of February 26th, 1920, the Military Affairs Committee* submitted the following communication to Engineering Council:

"1.—We believe it of vital National importance that sound Military Legislation should be enacted during the present session of Congress.

"2.—Effective provision for National defense with an adequate, organized, trained Army and Navy, sufficient to discharge our national and international obligations, is essential to security and stability, which must be present if our country is to go forward in constructive activity and achieve its possibilities as a nation.

"3.—The training of the entire youth of the nation and the establishment of organized reserves are indispensable provisions for National defense. With an adequate, organized citizen force, so that a minimum of professional soldiers is required, that maximum protection is afforded with a minimum of expense.

"4.—The careful selection and training of personnel and their assignment, when reservists, to organized reserve units, are vitally important to the efficiency of the technical services of the Army and Navy, and therefore essential to the proper preparedness of the individuals of the Engineering and allied professions and trades for the discharge of their constitutional obligations in National military service.

"5.—The full utilization of specially and technically qualified men and specialized industries has proved impossible where an organization was built up only after war had become imminent or had been declared.

"6.—The status of the membership of the National Engineering Societies with respect to all military matters, on which to base their plans for individual and collective preparedness, must remain indefinite until a military policy and principles of a military organization shall have been determined.

"7.—Therefore, we believe National security and stability can be assured only by application of the foregoing principles, in particular

* *Proceedings*, Am. Soc. C. E., February, 1920, p. 260.

the principle of universal military training and the creation of organized reserves, above all in the technical branches.

"We, therefore, recommend to Engineering Council that the President and Vice-President of the United States, the Secretary of War, the Secretary of the Navy, the Speaker of the House and the Chairmen and Members of the Military and Naval Committees of the Senate and the House be urged to incorporate the foregoing principles into any bills passed by either body for Army or Navy organization, and particularly the principle of universal training.

"We also recommend that each member of the Founder Societies (American societies of Civil, Mining, Metallurgical, Mechanical and Electrical engineers) be urged to study carefully the foregoing principles of military policy and in case, in the light of such study, he endorses said principles, to give his active support through letters to his Senators and Congressmen, or otherwise, to their incorporation in pending legislation."

The members of the Military Affairs Committee are as follows:

Col. Wm. Barclay Parsons, Chairman
Mr. Paul G. Brown, Vice-Chairman
Lt.-Col. George D. Snyder, Secretary
Col. Roger D. Black,
Mr. Harold W. Buck,
Col. Lincoln Bush,
Col. John J. Carty,
Col. H. S. Crocker,
Col. B. W. Dunn,
Maj. Arthur S. Dwight,
Capt. Alfred B. Fry,
Mr. George Gibbs,
Maj. Fred J. Miller,
Mr. Spencer Miller,
Col. F. A. Snyder,
Col. F. A. Molitor,
Col. G. R. Solomon,
Col. W. A. Starrett,
Dr. Leonard Waldo.

At a meeting of Engineering Council's Executive Committee on March 3d, 1920, it was voted to adopt the foregoing resolutions relating to the military policy of the United States prepared and recommended by the Military Affairs Committee.

Hearing on Nolan Patent Bill Before House Rules Committee

At a hearing before the Rules Committee of the House of Representatives, arranged by Edwin J. Prindle, Chairman of the Patents Committee of Engineering Council and Secretary of the Patents Committee of the National Research Council, a delegation of 68 representative men from many scientific, engineering, manufacturing and industrial organizations so impressed the Rules Committee that it granted the request that the Nolan Bill, H. R. 11 984 be placed on the calendar for an early hearing.

The Chairman of the Rules Committee stated that it was the most forceful and satisfactory hearing before that Committee during the past 10 years. Mr. Calvert Townley, as a representative of Engineer-

ing Council and President of the American Institute of Electrical Engineers, addressed the Committee and presented the resolution favoring the Nolan Bill authorized by Engineering Council at its Annual Meeting.*

Work of the Forest Products Laboratory

The Forest Products Laboratory, Madison, Wis., maintained by the Forest Service, U. S. Department of Agriculture, has been forced, through lack of funds, to reduce its working force until it now numbers about 200, one-third less than five months ago. The field of activity covered by the work of the Laboratory is suggested by the following lines of investigation undertaken:

Pulp and paper; hardwood and softwood distillation; preservation of wood; decay and decay prevention; mechanical properties of wood; glues for wood; kiln drying and air seasoning; grading structural timbers; grading lumber; boxing, crating, packing; chemistry of wood; needle and leaf oils; ethyl alcohol from wood waste; wood finishes, aircraft parts; veneers and plywood; steam bending; identification of wood, and microscopy of wood.

Among typical examples of the value of the work may be mentioned the following:

Boxing, Crating, Packing.—This work affects all shippers, railroads, express companies, and all consignees of goods which are boxed or crated, through the great saving which can be made by improved methods of packing.

Kiln Drying.—Improper methods of seasoning wood are causing great losses of lumber and money in all the wood-working trades, and are in no small degree responsible for the critical condition in which these industries find themselves to-day. They are not, however, the prime cause for this condition. To remedy these improper methods requires the thorough education of the industries in proper drying methods, in addition to special studies of commercial conditions.

Water-Resistant Glues.—Funds provided by the Army and Navy permitted the Laboratory to develop a number of water-resistant glues and to gather together a fund of knowledge about glues of these types which has been valuable in assisting many users of glue to solve various problems with which they are confronted. This work is of great importance to all wood-using industries. The development of still better and cheaper types of glues, indicated as readily possible by the work already done, must await more funds.

Pulp and Paper.—The increasing shortage of suitable pulpwood of the species most currently used for that purpose makes necessary the continuation of studies to determine the suitability of various other available woods for this purpose. An investigation of particular impor-

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* See page 344.

tance which should be conducted is that to determine the methods of preventing the enormous losses resulting from decay of ground wood pulp while in storage.

Presentation of Washington Award to Herbert Hoover

Formal presentation of the Washington Award for 1918 to Herbert Clark Hoover, M. Am. Soc. C. E., was made in Chicago on February 28th, 1920, under the auspices of Western Society of Engineers. Several hundred engineers awaited the arrival of Mr. Hoover, whose train was delayed, until nearly midnight, when presentation addresses were made by Charles F. Loweth, M. Am. Soc. C. E., Chairman of the Washington Award Commission, for the Western Society of Engineers; Onward Bates, M. Am. Soc. C. E., for The American Society of Civil Engineers; Charles H. MacDowell, for the American Institute of Mining and Metallurgical Engineers; James R. Bibbins, for the American Society of Mechanical Engineers; and Bion J. Arnold, M. Am. Soc. C. E., for the American Institute of Electrical Engineers.

Mr. Hoover, after accepting "as a tribute to the thousand engineers who were associated with him" made an address on the "Inter-relationship of General Industry and Food Production".

The text of the certificates of award is as follows:

" 'To be awarded to a member of the engineering profession who has accomplished much for the world about him in vital, important, far-reaching ways, and whose services in general have been noteworthy for merit in promoting the public welfare.'

"In these words were expressed the wishes of the Donor of the Washington Award.

"With Belgium's first cry of anguish, as war's tidal wave swept over that country, driving before and engulfing its people, an appeal came for a leader; for a man of character and experience; possessing great executive and co-operative ability; with courage to decide and act. The time was short. Upon such a man must devolve the stupendous task of organizing and administering a relief. The people of a nation must be fed and clothed, and at once, if the final phase of a great disaster was to be averted.

"That man was found. He was an engineer. His chief aids were engineers.

"The flow sheet of succor was drafted, and the finished mechanism of a relief program was soon functioning with little friction and with great efficiency.

"With the entrance of the United States into the world war, there arose again need for a leader,—one who could administer food problems on a still more gigantic scale; problems that related to our own requirements and to still more vital necessities of Europe. America must grow more field crops. The Allies must be sustained.

"The leader was found. He was an engineer. The work was done. Loyal American producers did their part.

"With the signing of the Armistice and with the break-down of morale among the enemy and in Eastern Europe, yet another pressing

problem had to be met. Further relief for war-disrupted peoples became a stern necessity. A man must be had equal to the needs of peace as well as the tasks of war.

"The man was found. He was an engineer.

"Then the negotiations for peace began. Amidst the intricate problems that arose, there emerged a clear call for a man with comprehensive knowledge of European conditions, with a grasp beyond the ordinary of food requirements and transport possibilities. Who should the man be? Once again, the engineer.

"From the end of the war until now, famine and disease have been rampant in Eastern Europe. Little folks, innocent children, have suffered, and are suffering. Young lives have been, and are being, sacrificed. Relief is vital. It has been established. The engineer is at the helm.

"In all of his urgent duties and his activities in many capacities, this engineer has not been found wanting. His colleagues everywhere have been uplifted by his deeds. They have been inspired to appreciation of a new and better kind of recompense for their professional labors—the recompense of a world's gratitude for unselfish public service.

"It is abundantly in keeping with the wishes of the Donor of the Washington Award to honor the engineer who has met these epochal emergencies; who has rendered unselfishly and efficiently a public service that has made many nations and peoples his debtor; and who has added so much to the luster and high standing of the engineering profession. Therefore, by authority vested in them, the Commission do hereby, through their chairman and in behalf of the Western Society of Engineers, confer the Washington Award for distinguished public service upon our eminent colleague,

HERBERT CLARK HOOVER."

Prefect of Constantinople Desires Engineer Specialists

A letter from the Prefect of Constantinople, Turkey, states that "it is intended to reconstruct the City of Constantinople on completely new plans in order to place it on the level of a modern Capitol, provided with all the modern hygienic, scientific, and artistic improvements which the town deserves according to its exceptional situation and climate."

He makes the request that he be put in touch with engineers and architects who are specialists along these lines. The address given is "Prefecture de la Ville, Cabinet du Prefet, Constantinople, Turkey."

EUROPEAN NOTES

The following notes relative to reconstruction, etc., in Belgium and France, and industrial progress, etc., in Great Britain and elsewhere, have been contributed by W. E. Woolley, Assoc. M. Am. Soc. C. E., of London, England, who is also a Corresponding Member of the Association of Liége (Belgium) Architects.

Law Provisions to Help Solve England's Housing Problem

To supplement the item on the "Housing Problem in England",* the following abstract of the recent Act of 1919 "to amend the enactments relative to the Housing of the Working Classes, Town Planning, and the Acquisition of Small Dwellings", indicates how the British Government has attempted to meet a serious situation.

The amended Act states that it shall be the duty of every local authority to consider the needs of their area with respect to houses for the working classes and, within three months of the passage of the Act or after notice has been given by the Local Government Board, to prepare and submit to the said Board a scheme for the exercise of their powers. Other clauses deal with the power of the local authorities to acquire land, and state the purposes for which land may be acquired; provision is also made for the assistance of public utility societies, housing trusts, etc., wherein it is stated that the local authority may promote the formation or extension of, or assist, a public utility society in matters of housing.

Local authorities may make loans to the owners of house property for the reconstruction, enlargement or improvement of existing housing accommodation. The conversion of large houses into several tenements, where the house cannot readily be rented as a single tenement, but could be let if divided into two or more, is authorized. However, the case must be proved to the satisfaction of the County Court on an application by the local authority or any person interested.

It is also provided that "The council of every borough or other urban district containing on the 1st of January, 1923, a population according to the last census * * * of more than 20 000 shall, within three years after that date, prepare and submit to the Local Government Board a town planning scheme * * *" so that, in effect, there will be compulsory town planning in the near future.

So pressing is the present need, now that many men have returned from military service, that in many places, as in Liverpool and Northampton, army huts have been erected to serve as temporary homes, and these are being let at extremely good rents.

Local authorities all over the country are now engaged on their housing schemes. Up to the end of August the number of schemes submitted to the Ministry of Health was 4 546, of which 1 419 have been approved, covering 18 200 acres. Plans have been approved which provide for 25 788 houses. The number of houses upon which building work has been begun is about 8 000, according to the Ministry's Housing Report.

If the owner of a house wishes to convert it into flats for the working classes, the Housing Act permits the local authority to loan a part or the whole of the necessary cash. It is suggested that the rate of

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* October–November–December, 1919, *Proceedings*, p. 961.

interest should be ½%, and the loan must not exceed half the value of the property. Terrace houses in groups can be readily converted into flats with one common staircase. Several London boroughs are taking up this matter, and it is stated that some 4 000 houses in the metropolitan area alone are suitable for such conversion into flats.

At present prices, the cost of erecting a small artisan's dwelling of a very plain type would be about £650, or about 1s. 2d. per cu. ft., about 2½ times as much as in 1914. Many authorities have received tenders considerably higher, even as high as £1 000 or £1 100.

Concrete has been advocated by many, largely as a cheaper material than brick, and has been used with success at several places, one notable example at Chepstow, Monmouth, where some hundreds of houses of this material, designed by well-known architects, have been erected. The walls are hollow, and are constructed of concrete blocks on the "Winget" principle, made by machines on the work.

Canal from the Elbe to the Danube

A Tcheco-Slovak Navigation Co. has been established at Pressburg with the object of canalizing towards this town the traffic from the Elbe to the Danube. It is stated that the preparatory negotiations have been terminated. The canal, which will have a length of 555 kilometers, will end at Pressburg, where a modern bridge will be erected. The company will have agencies at Hamburg, Aussig and in Roumania.

The Meuse Canal, Belgium

There is a strong movement in Belgium—which many notables are supporting—to canalize the middle Meuse from Liége to the Dutch frontier, making a boat canal to take 2 000-ton boats from Lische to Antwerp.

National Congress of Belgian Architects

The National Congress of Architects had expressed a wish that there should be organized a "Committee of Allotment or Distribution of Architectural Works", composed of nine members to be elected by the architects of the various devastated regions. This Committee has been formed, according to *La Libre Belgique,* but Flanders "Occidentale" is represented by an architect who is foreign to the province, and not a member of the only society of architects established there and affiliated with the Federation. The candidates of this society have been eliminated. The society protests and asks the competent ministry to intervene.

Rebuilding of Rheims

The Rheims Municipal Council has approved a rebuilding scheme submitted by Mr. George Ford, formerly an American Red Cross officer in France.

The areas destroyed by shell-fire during the war will be rebuilt with old-fashioned houses and thoroughfares in keeping with the rest of the town.

BRIEF NOTES

In concluding his address as retiring President of the Western Society of Engineers, A. S. Baldwin, M. Am. Soc. C. E., made the following significant statement: "As an Engineer, I have been endeavoring by cold analysis to resolve the most potent and practical force that is at the disposal of the Engineer for the accomplishment of great works, and I arrive at the conclusion that it is the force of Good Will. The world is in desperate need of it to-day, and I believe that when that force is fully and fairly recognized and used as a means to an end, the world will see works of magnitude and beauty so far in advance of the works of to-day as to be beyond the present conception of man."

The National Research Council has received from the Southern Pine Association a gift of $10 000 to pay for incidental expenses of a co-ordinated scientific study by a number of investigators of the re-growth of trees on cut-over forest lands, for the purpose of determining the best forestry methods for obtaining the highest productivity.

Nearly 75 colleges throughout the country are conducting campaigns for endowment funds to increase the pay of their professors and to provide new buildings and facilities. The estimated total sought is more than $200 000 000.

Plans for the reconstruction of the operating organization of the Pennsylvania Railroad system on termination of Government control on March 1st were adopted by the Board of Directors. Among the changes are greater unification of the system for operating purposes, establishment of a new organization affecting all departments and the creation of a regional plan of operation and management.

About one-third of the men of draft age in the United States are engaged in agriculture and allied occupations and another third in manufacturing and mechanical industries. This is shown by records of both the census and draft registrations. Nearly 9 000 000 men between the ages of 21 and 31 registered in the first draft.

Captain Craven, Director of Naval Aviation, told the House Naval Committee that two superdirigibles, the largest in the world, are

planned by the Navy, and that one of them now being built in England will attempt a transatlantic flight next fall.

It is announced from Naples that, in the opinion of American officials in Italy, more Italians will emigrate to the United States this year (1920) than in the record year of 1913, when 375 000 left that country for America.

New cable lines connecting the Brazilian ports of Santos and Rio de Janeiro with the present all-American cable system at Montevideo and Buenos Aires, provide direct communication between the United States and Brazil.

Americanization efforts in Cleveland have brought about a shifting of the foreign-born population, which is no longer confined to territories near industries. Formerly, the foreign-born were grouped in settlements. Now, with every industry fostering Americanization, these settlements are becoming mixed, and new districts are developing.

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, New Year's Day, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 6 P. M.

FUTURE MEETINGS

April 7th, 1920.—8.30 P. M.—A regular business meeting will be held, and a paper by Herbert C. Keith, M. Am. Soc. C. E., entitled "A Novel Method of Repairing a Swing Bridge," will be presented for discussion.

This paper was printed in *Proceedings* for February, 1920.

April 21st, 1920.—8.30 P. M.—At this meeting a paper by S. Johannesson and B. H. M. Hewett, Members, Am. Soc. C. E., entitled "Notes on Tunnel Lining" will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ENGINEERING SOCIETIES EMPLOYMENT BUREAU

Engineering Societies Employment Bureau, established December 1st, 1918, as an activity of Engineering Council, is managed by a board made up of the Secretaries of the four Founder Societies, funds for its maintenance being provided by these Societies. The Bureau is co-operating with Engineering organizations in all parts of the country and with the Re-employment Bureau under the auspices of the American Legion. It is desirous of increasing such co-operation by working with local engineering associations and clubs. The work of the Bureau since its inception has been largely in the line of securing employment for men retiring from government war service. Members of the American Society of Civil Engineers who desire to register with this Bureau should apply for further information, registration forms, etc., to Walter V. Brown, Manager, Engineering Societies Employment Bureau, First Floor, Engineering Societies Building, 29 West 39th Street, New York City.

SEARCHES IN THE LIBRARY

As the Library of the American Society of Civil Engineers has been merged in the Engineering Societies Library, requests for searches, copies, translations, etc., should be addressed to the Director, Engineering Societies Library, 29 West 39th Street, New York City, who will gladly give information concerning the charges for the various kinds of service. A more comprehensive statement in regard to this matter will be found on page 21 of the Year Book for 1920.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion will be published as heretofore in *Proceedings,* and set down for presentation to a future meeting of the Society, and, on these, oral discussion, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 35 of the Year Book for 1920.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association, Organized 1905.

M. M. O'Shaughnessy, President; Nathan A. Bowers, Secretary-Treasurer, 502 Rialto Building, San Francisco, Cal.

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Engineers' Club, 57 Post Street, on the third Tuesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at noon, every Wednesday, at the Engineers' Club, where special tables are reserved for members and guests of the Association.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association, Organized 1908.

W. C. Huntington, President; A. N. Miller, Secretary-Treasurer, 1400 West Colfax Avenue, Denver, Colo.

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesday, at 12.30 P. M., at Daniels and Fisher's.

Visiting members are urged to attend the meetings and luncheons.

Atlanta Association, Organized 1912.

V. H. Kriegshaber, President; Howard L. Stillwell, Secretary-Treasurer, 533 Trust Co. of Georgia Bldg., Care, Southeastern Underwriters' Association, Atlanta, Ga.

Informal luncheons are held for members of the Association on the last Monday of each month, at 12.30 P. M., to which visiting members of the American Society of Civil Engineers will be welcomed. The place is not fixed, but this information will be furnished on application to the Secretary.

Baltimore Association, Organized 1914.

H. G. Perring, President, 3206 Carlisle Avenue, Baltimore, Md.

Cleveland Association, Organized 1914.

W. P. Brown, President; George H. Tinker, Secretary-Treasurer, 516 Columbia Building, Cleveland, Ohio.

The regular meetings of the Association are held on the second Wednesday of each month, at 12.15 P. M., in the Rooms of the Electrical League, on the Fourteenth Floor of the Statler Hotel. Luncheon is served at these meetings, and visiting members are invited to attend.

(Abstract of Minutes of Meeting)

January 14th, 1920.—The meeting was called to order at 12.15 P. M.; President W. P. Brown in the chair; George H. Tinker, Secretary; and present, also, members and guests.

The minutes of the meeting of December 10th, 1919, were read and approved.

The report of the Secretary-Treasurer for 1919 was read, and on motion, duly seconded, was accepted and ordered filed.

The Chairman announced the appointment of the following Committees by the Executive Committee: Legislative Committee, Messrs. B. R. Leffler, E. J. Newton, and F. D. Richards; Member of the Joint Gas Committee, Mr. E. B. Thomas; and Director of the Association on the Board of Ohio Technical Societies, Mr. B. R. Leffler.

A communication from the Philadelphia Association relative to the adoption of the report of the Development Committee, was read, but no action was taken.

Relative to a communication from Engineering Council, it was voted, on motion, duly seconded, that the Board of Direction be advised that it is the sense of this Association that the Founder Societies pro-

vide sufficient funds to maintain Engineering Council until such time as a permanent organization is effected.

The Secretary read a communication from the Duluth Association in reference to the nine questions prepared by the Development Committee for submission to the membership. On motion, duly seconded, the Secretary was directed to request the Board of Direction to transmit a copy of its reply to the Duluth Association.

On motion, duly seconded, the Secretary was directed to write to the members of the Cuyahoga Delegation to the State Legislature, advising the passage of the Act to regulate the salaries and employment of County Draftsmen.

Adjourned.

Connecticut Association, Organized 1919.

C. M. Saville, President; R. J. Ross, Secretary, Municipal Building, Hartford, Conn.

The Annual Meeting of the Association is held in April. The Association also holds fortnightly meetings alternating between Hartford and New Haven, Conn. These meetings are informal luncheon gatherings held usually at noon on Saturday, a notice being mailed to each member calling attention to the date, time, place, and subject for discussion. Members are privileged to invite guests regardless of their affiliation as engineers. No set speeches are scheduled, but certain members are asked to be prepared to present the assigned subject and lead in a general discussion.

Detroit Association, Organized 1916.

Lewis M. Gram, President; Dalton R. Wells, Secretary-Treasurer, 624 McKerchey Building, Detroit, Mich.

The regular meetings of the Association are held on the second Friday of December, April, and October, the last being the Annual Meeting.

District of Columbia Association, Organized 1916.

David S. Carll, President; James H. Van Wagenen, Secretary-Treasurer, 719 Fifteenth Street, N. W., Washington, D. C.

(Abstract of Minutes of Meetings)

February 27th, 1920.—A special meeting for the purpose of discussing the Questionnaire Ballot on Development being voted on by the corporate members of the Society, was called to order at Cosmos Club Hall; President David S. Carll in the chair; James H. Van Wagenen, Secretary; and present, also, 48 members.

The minutes of the Annual Meeting of December 29th, 1919, were read and approved.

Mr. Arthur P. Davis, President of the Society, addressed the meeting, discussing in turn each question to be voted on. Messrs. George R. Putnam, D. E. McComb, C. W. Kutz, John H. Hanna, O. C. Merrill, E. C. Barnard, John S. Conway, E. F. Wendt, and W. A. Slater participated in the discussion which followed.

President Davis pointed out the inequality of the method of representation recommended by the Committee on Development by which

Local Associations of 100 members or more were to have one delegate and an additional delegate for each additional 1 000 members or major fraction thereof, while National Associations having 200 members were to have one delegate and an additional delegate for each 2 000 additional members or major fraction thereof. He said no valid reason existed for giving a heavier representation to the Local than to the National Societies. It had been urged that many of the members of the National Societies belong to local societies and would secure their representation in this way, but Mr. Davis said this argument might just as well be turned around by saying that local members were often members of the National Societies and might secure their representation through the latter. Claiming that no valid reason exists for the discrimination proposed, he favored the application of the same rule to both. He introduced the following resolution, which was seconded by Mr. Putnam and carried:

"*Resolved:* That the District of Columbia Association of Members of the American Society of Civil Engineers is in favor of giving the same basis of representation to all organizations forming the federation of Engineering Societies, whether such organizations are National or local, with a maximum limitation of representatives from any one Society."

Adjourned.

Duluth Association, Organized 1917.

G. A. Taylor, President; Walter G. Zimmermann, Secretary, Wolvin Building, Duluth, Minn.

The regular meetings of the Association are held at noon on the third Monday of each month (usually at the Kitchi Gammi Club), with luncheon, followed by a short business session and the reading of papers. Visiting members of the American Society of Civil Engineers can secure from the Secretary definite information relative to the meetings, at which they will be welcomed. The Annual Meeting is held on the third Monday in May.

Illinois Association, Organized 1916.

A. F. Reichmann, President; W. D. Gerber, Secretary-Treasurer, 913 Chamber of Commerce, Chicago, Ill.

The regular meetings of the Association are held on the second Monday of March, June, September, and December, the last being the Annual Meeting. The hour and place of meetings are not fixed, but this information will be furnished on application to the Secretary.

Iowa Association, Organized 1920.

J. E. Van Liew, President; R. W. Crum, Secretary, Iowa State College, Ames, Iowa.

Louisiana Association, Organized 1914.

A. T. Dusenbury, President; Eugene F. Deléry, Secretary, 602 Sewerage and Water Board Building, New Orleans, La.

The regular meetings of the Association are held at The Cabildo, New Orleans, La., on the first Monday of January, April, July, and October.

(Abstract of Minutes of Meeting)

February 9th, 1920.—The meeting was called to order; President Perrilliat in the chair; Eugene F. Deléry, Secretary; and present, also, members and guests.

On motion, duly seconded, the sum of $150 was appropriated for the National Public Works Association, and it was decided that it was the opinion of those present that the Jones-Reavis Bill be approved and that members of the Association be requested to do all in their power to further this end.

The officers for the ensuing year were elected, as follows: President, A. T. Dusenbury; First Vice-President, Ole K. Olsen; Second Vice-President, A. M. Shaw; Secretary, E. F. Deléry; and Treasurer, W. H. Williams.

On motion, duly seconded, it was decided to try to obtain papers on various subjects from members for presentation at future meetings of the Association.

Adjourned.

Nebraska Association, Organized 1917.

Clark E. Mickey, President; Homer V. Knouse, Secretary-Treasurer, 200 City Hall, Omaha, Nebr.

Regular meetings of the Association are held on the first Saturday of each month, except July and August, and at such places as may be appointed from time to time by the Executive Committee. The Annual Meeting is held in Lincoln, Nebr., on the second Friday in January.

Visiting members of the Society are especially urged to communicate with the Secretary when in the city.

New York Section, Organized 1920.

Robert Ridgway, President; Lewis D. Rights, Secretary, 256 Broadway, New York City.

The Annual Meeting is held in May. The times and places of other meetings are not fixed, but this information will be furnished on application to the Secretary.

(Abstract of Minutes of Meeting)

February 18th, 1920.—The first meeting of the Section, for organization, was called to order at the Engineering Societies Building. Present, 20 members.

Messrs. J. Waldo Smith and Clifford M. Holland were chosen temporary President and temporary Secretary, respectively. The object of the meeting was explained. Messrs. Walter E. Spear, Arthur S. Tuttle and George L. Lucas were appointed a committee to nominate officers.

Resolutions were passed declaring the Section formed, adopting the form of Constitution approved January 20th, 1920, by the Board of Direction and authorizing a general call to members of District No. 1 to join the Section.

The report of the Nominating Committee was presented and the following officers were elected, to serve until the Annual Meeting in May: President, Robert Ridgway; First Vice-President, J. Waldo Smith; Second Vice-President, Allen Hazen; Secretary, Lewis D.

Rights; Treasurer, Frederick C. Noble; and Directors, Otis E. Hovey and R. S. Buck.

On motion of Mr. S. N. Castle, the President was authorized to appoint representatives to participate in a joint conference of representatives of other local sections of National engineering and technical societies and local engineering societies. On motion of Mr. Hovey, the number of representatives was fixed at three.

The meeting was also addressed by Messrs. Daniel Bontecou, Arthur S. Tuttle, Herbert C. Keith, and Charles Hansel.

Adjourned.

Northwestern Association, Organized 1914.

Ralph D. Thomas, President; W. N. Jones, Secretary, City Engineer's Office, City Hall, Minneapolis, Minn.

The meetings of the Association are held bi-monthly, alternating between St. Paul and Minneapolis, on the third Friday of each month. Information as to the time and place of such meetings will be furnished on application to the Secretary.

Philadelphia Association, Organized 1913.

S. M. Swaab, President; Henry T. Shelley, Secretary, 416 City Hall, Philadelphia, Pa.

The regular meetings of the Association are held at the Engineers' Club of Philadelphia, 1317 Spruce Street, on the first Monday in January, April, and October, the last being the Annual Meeting. Special meetings will also be held during the winter, in order to provide an opportunity for members to take a more active part in the work of the Association.

(Abstract of Minutes of Meeting)

March 1st, 1920.—A special meeting was called to order at the Engineers' Club; President S. M. Swaab in the chair; H. T. Shelley, Secretary; and present, also, 40 members and guests.

The President introduced Maj. Walter Loring Webb as the speaker of the evening. Maj. Webb read an interesting paper on "The Work of the Valuation Section of the Renting, Requisitions and Claims Service of the United States Army in France." He was given an enthusiastic greeting from the members and was tendered a vote of thanks for his appearance before the Association.

Mr. Richard L. Humphrey spoke on the questionnaire submitted to letter ballot and of the sentiment in favor of the proposed development of the Society in different sections of the country. The subject was very generally discussed by the members present.

Adjourned.

Pittsburgh Association, Organized 1917.

Morris Knowles, President; Nathan Schein, Secretary-Treasurer, 426 City-County Building, Pittsburgh, Pa.

The Annual Meeting of the Association is held on the first Monday in October. The time and place of other meetings are not fixed, but this information will be furnished on application to the Secretary.

(Abstract of Minutes of Meeting)

February 27th, 1920.—The Special Meeting was called to order at 8 P. M., in the Union Arcade Auditorium; Vice-President N. S. Sprague in the chair; Nathan Schein, Secretary; and present, also, 60 members.

Chairman Sprague announced the purpose of this Special Meeting, namely, "To Consider the Secretaryship and Important Questions of Policy and also the Report of the Development Committee of the American Society of Civil Engineers".

The minutes of the previous meeting were read and approved.

The Secretary read all communications that had been received by him since the last meeting, which were ordered to be received and filed.

Mr. Richard L. Humphrey, of Philadelphia, Pa., addressed the meeting at length on the report of the Development Committee and also on the proposed federation of all engineering societies.

Mr. Richard Khuen, Chairman of the Internal Relations Committee, gave an informal talk on the progress of his Committee on the affiliation of engineers' societies in Pittsburgh.

On motion, duly seconded, this Committee on Local Affiliations was authorized to represent this Association at a conference relative to the organization of all engineering societies of the United States, which was authorized at the Annual Meeting of the Society.

On motion, duly seconded, a general discussion of Mr. Humphrey's address was ordered.

Mr. C. M. Reppert presented the following resolution:

"*Whereas*, The report of the Development Committee was endorsed by the Association at a previous meeting and approved at the Annual Meeting of the Society, and as the fundamental elements of the Development Report have been submitted in a questionnaire ballot by letter to the membership by the Board of Direction,

"*Therefore, be it Resolved*, That it is the sense of this Association that Questions "A", 1 to 3, inclusive, "External Relations," and Questions "B", 1 to 6, inclusive, "Internal Relations," should be answered in the affirmative, and Question "B"-7 in the negative; and that the President is hereby authorized and directed to appoint a committee of seven members to conduct a campaign to arouse interest and impress upon the membership of the Society in the Pittsburgh District, the importance of so voting upon the vital questions submitted in the ballot to insure the accomplishment of the recommendations of the Development Committee."

It was moved and seconded that this resolution be adopted.

The resolution was discussed by Messrs. George S. Davison, J. N. Chester, Richard Khuen, and Richard L. Humphrey.

The Secretary read communications from Director Edward E. Wall, of St. Louis, Mo., and Col. H. S. Crocker, relative to the Secretaryship of the American Society of Civil Engineers.

On motion, duly seconded, these communications were received and ordered to be filed.

Adjourned.

Portland (Ore.) Association, Organized 1913.

J. C. Stevens, President; C. P. Keyser, Secretary, 318 City Hall, Portland, Ore.

The Annual Meeting of the Association is held on the second Friday in January. Other meetings are called by the President and are usually convened on Friday evenings. The place is not fixed, but this information may be obtained on application to the Secretary. All members of the American Society of Civil Engineers are cordially invited to attend the meetings.

(Abstract of Minutes of Meeting)

January 9th, 1920.—The Annual Meeting was called to order at 8 P. M., at the University Club; President Thomson in the chair; C. P. Keyser, Secretary; and present, also, 36 members and 3 guests.

The minutes of the meeting of September 26th, 1919, were read and approved.

On motion, duly seconded, the bills were ordered to be carried over to the next meeting, pending the Treasurer's report.

Reporting back from the Conference on Co-ordination of Local Technical Organizations, President Thomson read a draft of a proposed Constitution for the Oregon Technical Council, which, on motion, duly seconded, was adopted, as amended, section by section. The subject was discussed by Messrs. Reed, Edmondstone, Dieck, Plummer, Mason, Stevens, Hoffmark, Purcell, and Henny.

In reference to the use of a union label on working drawings, the Secretary presented a resolution which he stated he had prepared and referred to the Secretary of the Society, who, in turn, had referred the whole matter to Engineering Council. A letter from the Secretary of Engineering Council was read, asking for further information on the subject, and stating that the matter would be presented at the meeting of the Council on December 18th, 1919. Nothing further had developed and, on motion, duly seconded, the question was laid on the table.

Mr. R. F. Hoffmark, Chairman of the Committee on Resolution favoring the Jones-Reavis Bill, offered the following resolution which, on motion, duly seconded, was adopted:

"*Whereas,* The Portland Chapter of the American Society of Civil Engineers believes that the passage of the Jones-Reavis Bill for the creation of a Department of Public Works would greatly add to the efficiency of Government activities along technical and scientific lines and that it would terminate the costly and antiquated methods of division of these activities over numerous bureaus scattered through nearly all the departments of our Government, it is

"*Resolved,* That we urge upon our representatives in Congress that they give this measure their energetic support and that a copy of this resolution be mailed to each member of the Oregon Congressional delegation and to the public press."

Mr. D. C. Henny, Chairman of the Oregon State Committee on National Department of Public Works, outlined the work of that Committee and stated that, through co-operation with Spokane and Seattle, Mr. J. C. Ralston had been sent as a delegate from District No. 12 to

the Conference to be held in Washington, D. C., on January 13th, 1920. On motion, duly seconded, it was voted that the Association concur in the nomination of Mr. Ralston as its delegate to the Conference.

In reference to the questionnaire report, Mr. G. C. Mason reported that it had been filed with the Committee on Development of the Society, and was in *statu quo* awaiting the action of the Society on the Development Committee's report.

On motion, duly seconded, the Association subscribed $5.00 for membership in the Oregon Irrigation Congress.

On motion, duly seconded, the Association approved the report of the Development Committee, and the Secretary was instructed to advise the Board of Direction that the Association strongly favors action on the report.

Mr. G. B. Hegardt called attention to the need for funds to complete the Engineering Laboratory at the Oregon Agricultural College, and, on motion, duly seconded, the Secretary was instructed to draft and transmit a resolution favoring such effort.

The Secretary read the Annual Report of the officers. Owing to the illness of the Treasurer, the financial statement was omitted, and, on motion, duly seconded, the Secretary was instructed not to file the report until a subsequent meeting.

The Secretary presented a communication from Mr. J. C. Stevens in which he invited all members who were members of the Chamber of Commerce to lunch there at a table which had been reserved for technical men. Mr. M. E. Reed called the attention of the members to the hospitality of the University Club, suggesting that members lunch there, and, on motion, duly seconded, the Secretary was instructed to convey an expression of appreciation by the Association to the officers of the University Club for courtesies extended to the Association.

The Secretary read a communication from Mr. Harry Hawgood, in which he requested an expression of preference of cities in District No. 11 as a place for holding the Annual Convention of the Society. President Thomson directed the Secretary to reply that the Association would prefer Los Angeles, Cal., to any other city in District No. 11.

President Thomson appointed Messrs. W. G. Brown and P. H. Dater as Tellers in the annual election of officers, and, on their report, the following officers were declared elected: President, J. C. Stevens; Second Vice-President, F. M. Randlett; Treasurer, C. J. McGonigle; and Secretary, C. P. Keyser.

Mr. Mason addressed the meeting on "Some Aspects of Industrial Development", and was followed by Mr. Robert G. Dieck on "Municipal and Harbor Improvements with Particular Reference to the Development of Industrial Sites".

Adjourned.

St. Louis Association, Organized 1888 (Constitution Approved by Board, 1914).

Edward E. Wall, President; C. W. S. Sammelman, Secretary-Treasurer, 300 City Hall, St. Louis, Mo.

The Annual Meeting of the Association, for the election of officers and for the transaction of business, is held on the fourth Monday in November. Two meetings each year, for the presentation and discus-

sion of technical papers, are held in the Auditorium of the Engineers' Club of St. Louis and are open to members of the Associated Societies. Other "get-together" meetings are held regularly for dinner or luncheon on the fourth Monday of each month except July, August, and November.

(Abstract of Minutes of Meetings)

November 24, 1919.—The meeting was called to order at 12.15 P. M., at the American Hotel; President J. A. Ockerson, in the chair; S. Sammelman, Secretary; and present, also, 21 members and guests.

The minutes of the previous meeting were read and approved.

A letter from C. T. Chenery, Secretary of the Engineers', Architects', and Constructors' Conference on National Public Works, was read and referred to Mr. Baxter L. Brown.

The Secretary read a communication from Mr. Harry Hawgood, Director from District No. 11, requesting an expression of the Association's preference in regard to holding the Annual Convention of the Society at Los Angeles, Cal., or Houston, Tex. A vote of those present showed 13 favoring Houston, 4 favoring Los Angeles, and 6 not voting.

A letter soliciting funds for the support of Engineering Council was read, and, on motion, duly seconded, it was decided that Council be supported and Secretary Flinn be notified of the action of the Association.

The report of the Secretary was read and approved. The report of the Treasurer was presented, and, on motion, duly seconded, he was instructed to submit it to the Executive Committee to be audited.

The Nominating Committee, consisting of Messrs. H. P. Taussig, W. S. Dawley, and W. E. Rolfe, reported on nominees for officers of the Association for 1920, as follows: President, Edward E. Wall; Vice-Presidents, J. W. Woermann and E. B. Fay; Secretary-Treasurer, S. Sammelman; and as representatives of the Association on the Joint Council of the Associated Engineering Societies, Messrs. F. G. Jonah and W. J. Burton.

On motion, duly seconded, it was ordered that further nominations be closed, and that the Secretary be instructed to cast a ballot declaring those designated by the Nominating Committee to be elected for the ensuing year.

President Ockerson turned over the chair to President-elect Wall, and a rising vote of thanks was tendered Mr. Ockerson for the efficient and effective work he had accomplished during his term of office as President.

President Wall reported on the proceedings of the meeting of the Board of Direction of the Society held in New York City.

On motion, duly seconded, it was ordered that the meetings of the Association be continued on the fourth Monday of each month, and that the decision as to whether they be noonday or evening meetings be left to the judgment of the President.

Adjourned.

December 15th, 1919.—The meeting was called to order at the American Hotel; President Edward E. Wall in the chair; S. Sammelman, Secretary; and present, also, 25 members and guests.

The minutes of the previous meeting were read and approved.

The President presented the report of the Special Committee appointed by the Board of Direction to study and review the report of the Development Committee. After a lengthy discussion of Part 1 of the report, and Appendix A, it was the opinion of the members present that the scheme for a Joint Engineering Council, outlined in Appendix A, was in no way preferable to the proposition of the Joint Conference Committee as set forth under the head of "National Engineering Organization" on page 12 of the report of the Development Committee.

President Wall presented a scheme for a National Engineering Organization following out the ideas of the Joint Conference Committee, but modifying its recommendations as to the basis of representation. This proposition met with the unanimous approval of the members present, and it was duly moved, seconded, and carried that it was the sense of the meeting that the modified scheme for a National Engineering Organization as presented by President Wall was preferable to anything considered so far, and that this scheme was approved and recommended to the Committee for its consideration.

The remainder of the Alvord Committee's report was considered, and, in the main, was satisfactory to the meeting, although there was considerable discussion over the question of doing away with the resident membership and raising the dues as much as $10.00 per member. It was finally decided to leave the matter open until more details were submitted through the Board of Direction as to the manner in which the increased revenue would be expended.

The meeting then took up the report of the Development Committee, commencing with Division D. The general conclusion as to the definition of "Engineering" was that such a definition should be left very general and could not be made specific; also that an effort to define an engineer so that he could be easily segregated from artisans and mechanics was exceedingly difficult, and in any event was not necessary for the purpose of drawing up a satisfactory statute for either the licensing or registration of engineers. The recommendations of the Committee on "Engineering Education" and "Arbitration and Expert Testimony" were approved by the meeting.

Adjourned.

San Diego Association, Organized 1915.

W. C. Earle, President; R. C. Wueste, Secretary-Treasurer, Bonita, Cal.

Seattle Association, Organized 1913.

John L. Hall, President; Bertram D. Dean, Secretary, 1711 Ravenna Boulevard, Seattle, Wash.

The regular meetings of the Association, with luncheon, are held at the Engineers' Club, Arctic Building, Third Avenue and Cherry Street, at 12.15 P. M., on the last Monday of each month. Informal luncheons are also held at 12.15 P. M., every Monday at the Engineers' Club.

Special evening meetings are held from time to time for the purpose of discussing important topics, and information concerning these meet-

ings may be had by addressing the Secretary. All members in any grade of the American Society of Civil Engineers are cordially invited to attend the meetings when in the vicinity, and, if located in this District for any length of time, their membership in the Association will be appreciated.

(Abstract of Minutes of Meeting)

February 9th, 1920.—The Annual Meeting was called to order at 8 P. M., at the Engineers' Club; President L. M. Grant, in the chair; Glenville A. Collins, Secretary; and present, also, 30 members and guests.

The minutes of the last meeting were approved, as read.

The Secretary read the Annual Reports of the Secretary and Treasurer, and also a letter from Mr. J. C. Ralston giving a detailed report on his activities in Washington, D. C., on behalf of the Association, regarding the Department of National Public Works.

On motion, duly seconded, and passed unanimously, the Secretary was instructed to thank Mr. Ralston on behalf of the Association for his able report of work accomplished.

Officers for the ensuing year were elected as follows: John L. Hall, President; Carl H. Reeves, Vice-President; and Bertram D. Dean, Secretary-Treasurer.

After the installation of the new officers, addresses were given as follows: By Col. J. A. Woodruff, Engineer Corps, U. S. A., on "The Work of the Division of Construction and Forestry in France"; by Prof. C. C. More, of the University of Washington, on "The Engineers' School at Camp A. A. Humphreys"; and by A. H. Dimock, City Engineer, on "The Skagit River Power Development".

Adjourned.

Southern California Association, Organized 1914.

W. K. Barnard, President; Floyd G. Dessery, Secretary, 514 Central Building, Los Angeles, Cal.

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular monthly meetings on the second Wednesday of each month, the December meeting being the Annual Meeting.

Informal luncheons in connection with the Joint Technical Societies of Los Angeles are held at 12.15 P. M., every Thursday at the Broadway Department Store Café.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

(Abstract of Minutes of Meeting)

February 11th, 1920.—The meeting was called to order at 7.50 P. M., at the Jonathan Club; President W. K. Barnard in the chair; F. G. Dessery, Secretary; and present, also, 32 members and 9 guests.

The minutes of the January meeting were approved, as written.

President Barnard announced the death of Andrew Christian Hansen, a member of the Association and City Engineer of Los Angeles, Cal., and thereupon a committee consisting of Messrs. William Mulholland, E. T. Wheeler, and E. R. Bowen, presented the following

resolution, which was adopted unanimously and ordered to be transmitted to Mr. Hansen's widow:

> "*Whereas*, it has pleased the Almighty to remove from our midst our distinguished and beloved brother engineer and esteemed friend, Andrew Christian Hansen, and
>
> "*Whereas*, Andrew Christian Hansen has especially distinguished himself by his valued public work rendered to the City of Los Angeles, and by his kindly, courteous, and manly attitude toward his fellow-men,
>
> "*Therefore, be it Resolved*, that we hereby express our deep sense of the great loss to this Association, and to the community he so well served.
>
> "*We further* express and tender our sincere sympathy to his bereaved family, and implore the all-wise Almighty, in whose bosom our departed brother rests, to sustain and comfort these relatives in this, the hour of their affliction."

A letter from the Hon. Meredith P. Snyder, Mayor of Los Angeles, transmitting to the Association a copy of a report on Railroad Grade Crossing and Terminal Investigation in Los Angeles, was read, and, after considerable discussion, it was determined to be the sense of the meeting that this report be referred to a special committee to be appointed by the Board of Directors, to report to the Association at its next meeting. The Board of Directors appointed the following to serve on the Special Committee: Messrs. Reed, Anderson, and Dennis.

The Secretary read a letter and resolution (dated January 29th, 1920) from the St. Louis Association, criticising the action of the Board of Direction at the 67th Annual Meeting relative to the appointment of Dr. Charles Warren Hunt as Secretary Emeritus. After explanations by Director Hawgood who had attended the meeting at which this action was taken, the matter appeared in an entirely different light, the final vote approving Dr. Hunt's appointment being 16 to 10 and not 15 to 13 as stated in the communication from the St. Louis Association.

The Secretary read a letter and a copy of a resolution adopted by the Joint Council of the Engineering Societies of San Francisco (January 27th, 1920), inviting the Association to endorse Mr. Herbert C. Hoover for President of the United States. After considerable discussion, on motion by Maj. Leeds, with two dissenting votes, the resolution from the Joint Council of the Engineering Societies of San Francisco was ordered to be modified to comply with the requirements of the Association and was endorsed as the sentiment of the meeting.

President Barnard introduced Mr. Roy V. Reppy, Chief Counsel of the Southern California Edison Company, and formerly in charge of flood control matters in the County Counsel's office, who presented a paper on "Political and Legal Aspects of Flood Control in Los Angeles County", and Mr. W. H. Code read a paper on "Financial Features and Executive Organizations Provided in the California Conservancy Act". These two papers threw much light on the legal and executive sides of the existing Flood Control Acts.

Director Hawgood made an extensive report relative to the 67th Annual Meeting of the Society, and explained the action of the Board

of Direction in holding the next Annual Convention in Houston, Tex., as being caused by the desire to stimulate membership in the South. He also advised that the Board of Direction will meet in Los Angeles in July, 1920, the exact date to be decided later.

Mr. Hawgood also discussed the progress made on the report of the Committee on Development, advising that within a short time, a questionnaire on the report would be submitted to the membership for ballot. The discussion of the report of the Committee on Development, which ensued, brought out the necessity of individual action and voting, in order to overcome objections to it. The necessity for individual effort as well as teamwork was pointed out by Mr. G. G. Anderson, and, on motion, duly seconded, it was determined that, at the next meeting of the Association, precedence in the order of business be given to a consideration of the proposed questionnaire, and the report of the Committee on Development in general, followed by discussions of Flood Control papers, if such papers were offered.

Owing to the lateness of the hour, a lengthy communication from Mr. Samuel Storrow on the lack of proper compensation of naval officers, on motion, duly seconded, was laid on the table.

Adjourned.

Spokane Association, Organized 1914.

Alfred D. Butler, President; Charles E. Davis, Secretary-Treasurer, 401 City Hall, Spokane, Wash.

The regular meetings of the Association are held on the second Friday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Visiting members are invited to attend the meetings.

Texas Association, Organized 1913.

Hans Helland, President; E. N. Noyes, Secretary, Deere Building, Dallas, Tex.

Utah Association, Organized 1916.

A. B. Villadsen, President, 304 Dooly Bldg., Salt Lake City, Utah.

The Annual Meeting of the Association is held on the first Wednesday in April. The time of other meetings is not fixed, but this information will be furnished on application to the President.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcome in the Reading Rooms and at the meetings of many engineering societies in all parts of the world. A list of such societies will be found on pages 42 and 43 of the Year Book of the Society for 1920.

Upon request by its Board of Trustees, the Engineering Societies of Wisconsin, Madison, Wis., is to be added to the above-mentioned list, and its members are accorded the usual courtesies and privileges of the Headquarters of the Society.

NEW BOOKS*

(From February 1st to February 28th, 1920)

The statements made in these notices are taken from the books themselves, and this Society is not responsible for them.

DONATIONS TO ENGINEERING SOCIETIES LIBRARY

EFFICIENT BOILER MANAGEMENT:

With Notes on the Operation of Reheating Furnaces. By Chas. F. Wade. Lond. and N. Y., Longmans, Green & Co., 1919. 14 + 266 pp., illus., tables, 9 x 6 in., cloth. $4.50.

The author of this work endeavors to explain, in their proper sequence, the elementary scientific principles underlying the various subjects combined in boiler management and the systematic practical application of these principles to obtain the greatest efficiency. The book is intended to fill the gap between the treatises on the chemistry of combustion, etc., in which practical applications are omitted, and the practical text-books on boiler plants, which give little attention to the fundamental principles governing their operation.

ENGINEERING MACHINE TOOLS AND PROCESSES:

A Text-Book for Engineers, Apprentices, and Students in Technical Institutes, Trade Schools, and Continuation Classes. By Arthur G. Robson. Lond. and N. Y., Longmans, Green & Co., 1919. 307 pp., illus., tables, 9 x 6 in., cloth. $4.00.

This work presents a course in the systematic study of machine work and machine tools which is practical rather than theoretical in character. The methods and machines described are those used in British shops, and the volume is intended for use in that country.

AMERICAN GAS WORKS PRACTICE:

Standard Practical Methods in Gas Fitting, Distribution, and Works Management. By George Wherle. N. Y., Progressive Age Publishing Co., 1919. 741 pp., illus., tables, 8 x 6 in., cloth. $4.00.

This work is intended as a general reference book on gas-works practice in the United States, with special emphasis on gas-fitting practice. Approximately one-half of the book is devoted to the latter topic, and the methods used in street and house distribution, standards adopted, etc., are fully described.

CHILTON AUTOMOBILE DIRECTORY, JANUARY, 1920.

Published Quarterly. Phila., Chilton Co. 1 000 pp., 10 x 6 in., cloth. $5.00.

This quarterly directory of the automobile industry contains a classified list of the American manufacturers of passenger and commercial motor cars, automobile equipment, parts, and machinery for their manufacture. The arrangement is alphabetical, and the classification is quite detailed. In addition, the book contains a directory of automobile trade associations, a table of the serial numbers of American motor cars, the standards of the Society of Automotive Engineers, and various engineering tables.

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* Unless otherwise specified, books in this list have been donated by the publishers

MANUFACTURE AND USES OF ALLOY STEELS.

By Henry D. Hibbard. (Wiley Engineering Series.) N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1919. 14 + 96 pp., 9 x 6 in., cloth. $1.25.

In this monograph, the author has tried to give briefly information of present value relating to the manufacture and uses of the various commercial alloy steels, with the hope of stimulating the demand for them and extending their practical use. The steels considered are tungsten, chromium, manganese, nickel, silicon, nickel-chromium, chromium-vanadium, and high-speed tool steels. Bibliographies are given for each.

TECHNICAL METHODS OF ORE ANALYSIS.

By Albert H. Low. 8th edition. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1919. 388 pp., 21 illus., tables, 9 x 6 in., cloth. $3.25.

This manual is intended primarily for the technical chemist, for whom it provides a collection of tested short technical methods adapted to the cases most likely to be met in practice, which are described with minute detail. The present edition has been thoroughly revised, and a number of new methods have been added.

PROSPECTING FOR OIL AND GAS.

By L. S. Panyity. N. Y., John Wiley & Sons, Inc., 1920. 249 pp., 123 fig., 28 tab., 8 x 5 in., cloth. $3.25.

This work is written for practical oil men and the general public interested in oil investments. It is intended to provide an account of the tools and methods used by scientific prospectors for oil and gas which will enable those without special knowledge of geology to realize what may be expected of the geologist, to analyze a geological report, and to pass judgment on its merits. The book is based on a study of the literature and the practical experience of the author, who is a member of the American Institute of Mining and Metallurgical Engineers.

THE LABOR MARKET.

By Don D. Lescohier. N. Y., The Macmillan Co., 1919. 338 pp., 9 charts, 8 x 5 in., cloth. $2.25.

This work is intended for general readers, employers, legislators, employment officials, college teachers, and students of the employment and labor problem. The factors of supply and demand, labor market machinery, and special employment problems are discussed. The author advocates National control of the problem of employment. An extensive bibliography is included.

FATIGUE STUDY:

The Elimination of Humanity's Greatest Unnecessary Waste, a First Step in Motion Study. By Frank B. Gilbreth and Lillian M. Gilbreth. N. Y., The Macmillan Co., 1919. 175 pp., plates, 8 x 5 in., cloth. $1.50.

This book is a study of fatigue in workmen and its prevention. It aims to determine what fatigue results from various types of work, how unnecessary fatigue may be eliminated, and necessary fatigue reduced to a minimum. Numerous appliances and methods are described.

APPLIED MOTION STUDY:

A Collection of Papers on the Efficient Method to Industrial Preparedness. By Frank B. Gilbreth and L. M. Gilbreth. N. Y., The Macmillan Co., 1919. 220 pp., plates, 1 chart, 8 x 5 in., cloth. $1.50.

This collection describes the application of motion study in various fields of activity and the methods by which it is applied. It also gives the results obtained in various cases and suggests the fields in which it may be used with benefit.

TIME STUDIES FOR RATE SETTING.

By Dwight V. Merrick, with a Foreword by Carl G. Barth. N. Y., The Engineering Magazine Company, 1919. 366 pp., 137 fig., 9 x 6 in., leather. $6.00.

The author presents in amplified form the principles covering time study for rate setting, describes various mechanisms that have been found helpful in making and using such studies, and presents some details of practice. An example of the application of time studies to a line of machine tools is included, together with detailed times for a number of other kinds of work.

SAFETY FUNDAMENTALS:

Lectures Given by the Safety Institute of America (Maintaining The American Museum of Safety). N. Y., Safety Institute of America, 1920. 228 pp., illus., plates, 8 x 5 in., cloth. $2.00.

These lectures were delivered during 1919 before an audience of factory inspectors employed by the City of New York, the States of New York and New Jersey, and insurance companies in and near New York. They are intended to enlarge the knowledge and increase the experience of inspectors with respect to the various fundamentals that affect the mind and body of the workman. Contents: The Body Which Gets Hurt; The Injured Body and Its Treatment: (*a*), Protective Clothing for Men; (*b*), Suitable Work Garments for Women in Industry; Safe Heads and Good Eyes; Guarding Machinery; Arrangement of Machinery and Working Places; Heating and Ventilation; Illumination; Nature's Forces For and Against Workmen; Safety Education and Shop Organization.

ENGINEERING EDUCATION:

Essays for English, Selected and Edited by Ray Palmer Baker. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1919. 185 pp., 8 x 5 in., cloth. $1.25.

Under these headings the Professor of English in the Rensselaer Polytechnic Institute has grouped fourteen essays, written by prominent American and English engineers during the past decade, which deal with various aspects of engineering education. The book is intended for use in elementary courses in exposition in schools of engineering. Contents: The Origins of Engineering Education; The Types of Engineering Education; The Bases of Engineering Education.

INORGANIC CHEMICAL SYNONYMS

And Other Useful Chemical Data. By Elton R. Darling. N. Y., D. Van Nostrand Co., 1919. 100 pp., 7 x 4 in., cloth. $1.00.

The author has collected the various synonyms that have been used in scientific and trade literature to designate the chemicals in common use and has arranged them so that the substance in question can be accurately identified.

PRINTING TRADES BLUE BOOK:

National Edition, 1920. Chicago, Edited and Published by A. F. Lewis & Co. 287 pp., 8 x 6 in., cloth.

This directory contains the names and addresses of manufacturers of printers' and bookbinders' supplies and equipment, arranged by firm names and lines. It is intended for makers and users of printed matter.

MUNICIPAL ENGINEERING PRACTICE.

By A. Prescott Folwell. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1916. 422 pp., illus., plate, 1 table, 1 map, 9 x 6 in., cloth. $3.50.

The author of this volume has tried to provide a text-book treating of all those matters which enter into the work of a city engineer, with the exception of sewerage, water supply, and street paving. City plans, street details, bridges and waterways, city surveying, street lights, signs and numbers, street cleaning and sprinkling, waste disposal, markets, comfort stations, baths, parks, cemeteries, and shade trees are discussed at greater or less length.

PARKS AND PARK ENGINEERING.

By William T. Lyle. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1916. 130 pp., illus., plates, 1 map, 9 x 6 in., cloth. $1.25.

This book is prepared for the benefit of inexperienced engineers, but will also, the author hopes, be useful to members of newly formed park associations and commissions. Contents: Desirability and Acquisition of Parks; Lands and Surveys; Design; Labor and Contracts; Construction.

MODERN ROADS.

By H. Percy Boulnois. Lond., Edward Arnold, 1919. 302 pp., 13 plates, figures, charts, tables, 8 x 5 in., cloth. $5.75.

This book is intended as a comprehensive survey of the present status of road construction and maintenance in Great Britain. Water-bound macadam roads, tarred, concrete, and bituminous roads and pavements are included, together with chapters on bituminous carpets, waves and corrugations, and slippery streets.

HIGHWAY INSPECTORS' HANDBOOK.

By Prévost Hubbard. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1919. 372 pp., 55 illus., diagrams, tables, 7 x 4 in., flexible cloth. $2.50.

The author has endeavored to present most of the important details of highway construction and maintenance, as briefly as possible, in such form as to be quickly available to the inspector who wishes to be told what to do rather than what others have done under similar circumstances. Considerable explanatory matter has been included, and diagrams have been used freely to present data in convenient form for field use. The volume is of convenient size for the pocket.

MEMBERSHIP

(From February 7th to March 4th, 1920)

ADDITIONS

MEMBERS

Members		Date of Membership.
BELL, HARRY WALTON. Cons. Engr., Montrose, Miss.	Assoc. M.	Nov. 12, 1913
	M.	Oct. 15, 1920
CAMPBELL, CARROLL ALFRED. Director of Public Works, City of Middletown, Box 758, Middletown, Conn.		Jan. 19, 1920
COLE, ERNEST DELEVAN. Asst. Engr., Empire Gas & Fuel Co., Bartlesville, Okla.	Jun.	Oct. 31, 1911
	Assoc. M.	Feb. 4, 1913
	M.	Oct. 15, 1919
EMORY, LLOYD TILGHMAN. Civ., Chemical, and Industrial Engr. (Emory & Eisenbrey), 919 Harrison Bldg., Philadelphia, Pa.	Jun.	Oct. 5, 1909
	Assoc. M.	April 2, 1912
	M.	Jan. 20, 1920
FORD, HOWARD CARLTON. 1356 Newton St., Denver, Colo.	Jun.	Sept. 1, 1908
	Assoc. M.	May 31, 1910
	M.	Jan. 20, 1920
FOUNTAIN, THOMAS LILLY. Agricultural and Mech. Coll., College Station, Tex.	Jun.	April 2, 1907
	Assoc. M.	April 6, 1909
	M.	Oct. 15, 1919
KNOWLTON, LYNN ORLANDO. Archt. (Bass, Knowlton & Graham), 801 Hume Mansur Bldg., Indianapolis, Ind.		Jan. 19, 1920
LENDERINK, ANDREW. City Engr. (Res., 632 Summer St.), Kalamazoo, Mich.	Assoc. M.	Oct. 1, 1912
	M.	Jan. 20, 1920
MANDIGO, CLARK ROGERS. Chf. Engr., Western Paving Brick Mfrs. Assoc., 317 Dwight Bldg. (Res., 3745 Flora Ave.), Kansas City, Mo.	Assoc. M.	Sept. 3, 1912
	M.	Jan. 20, 1920
SALISBURY, ALFRED JAMES, JR. Cons. Hydr. Engr., 406 Mortgage Guarantee Bldg., Los Angeles, Cal.	Assoc. M.	Mar. 14, 1916
	M.	Jan. 20, 1920
SHEIBLEY, EDWARD GWYN. San. Engr. and Mgr. (Private Practice), Care, University Club, Los Angeles, Cal.	Assoc. M.	Mar. 14, 1916
	M.	Jan. 20, 1920
STEVENS, CHARLES HENRY. Head Draftsman, Dept. of City Transit, 1211 Chestnut St. (Res., 5918 North Park Ave.), Philadelphia, Pa.	Assoc. M.	May 6, 1914
	M.	Jan. 20, 1920
TURNER, ARTHUR JOHN. Chf. Engr., Columbia Basin Survey Comm., 2203 Jackson Ave., Spokane, Wash.	Assoc. M.	Mar. 2, 1915
	M.	Jan. 20, 1920
WEAKLEY, FRANK MERRILL. Gen. Contr., 315 North St., Portsmouth, Va.		Jan. 19, 1920
WYSE, FREDERICK CALHOUN. City Engr., Columbia, S. C.	Assoc. M.	July 2, 1913
	M.	Jan. 20, 1920

ASSOCIATE MEMBERS

Name and Address	Grade	Date of Membership.
ALVAREZ, ARTHUR CARL. Associate Prof. of Civ. Eng., Univ. of California, 1909 Dwight Way, Berkeley, Cal.		Jan. 19, 1920
ASHKINS, NATHAN THOMAS. Care, J. B. Carson, 1233 Elden Ave., Los Angeles, Cal.	Jun.	Jan. 15, 1917
	Assoc. M.	Jan. 19, 1920
BAKER, DONALD MCCORD. Engr., State Water Comm., 632 Call Bldg., San Francisco, Cal.	Jun.	Dec. 3, 1913
	Assoc. M.	Jan. 19, 1920
BARRY, EDMUND JOSEPH. Maj., Engrs., U. S. A.; Const. Q. M., Fort Leavenworth, Kans.	Assoc.	Oct. 8, 1918
	Assoc. M.	Jan. 20, 1920
BATEMAN, JOHN HENRY. Asst. Prof. of Civ. Eng., Univ. of Michigan; Testing Engr., Michigan State Highway Dept., Care, Highway Laboratory, Univ. of Michigan, Ann Arbor, Mich.		Jan. 20, 1920
BEHNEMAN, STANLEY ELGIN CLINTON. Asst. Engr., United Railroads of San Francisco, 4667 Eighteenth St., San Francisco, Cal.		Oct. 14, 1919
BOLIN, HARRY WILLIAM. Engr., H. J. Brunnier, 312 Sharon Bldg., San Francisco, Cal.	Jun.	May 6, 1914
	Assoc. M.	Jan. 19, 1920
BUCK, BERTIE HARRISON. Chf. Engr., Great Southern Lumber Co.; Chf. Engr., Bogalusa Paper Co., Box 56, Bogalusa, La.		Jan. 19, 1920
COBURN, CLARENCE ALONZO. Engr. and Contr. (Coburn & Co.), St. George's Bldg., Hongkong, China		Jan. 20, 1920
CONWAY, CLARENCE DEXTER. Supt. and Engr., Los Molinos Land Co., Los Molinos, Cal.	Jun.	Nov. 28, 1916
	Assoc. M.	Jan. 19, 1920
DUGAN, CHARLES BEDARD. 202 Hartman Bldg., Columbus, Ohio		Jan. 19, 1920
FORBES, HYDE. With Lindsay-Strathmore Irrig. Dist., Lindsay, Cal.	Jun.	Oct. 10, 1916
	Assoc. M.	Jan. 19, 1920
GRUNDEL, IRVING GEORGE. Supt., Avila Refinery, Union Oil Co. of California, Avila, Cal.		Jan. 19, 1920
HANNAMAN, DONALD ARMSTRONG. 906 North Division St., Salisbury, Md.		Nov. 25, 1919
HOLLAND, ARTHUR FRANCIS. Care, the H. Koppers Co., Const. Dept., Union Arcade Bldg., Pittsburgh, Pa.		Oct. 14, 1919
HOLST-GRUBBE, TRYGVE. Care, Gunvald Aus Co., 244 Madison Ave., New York City		Jan. 19, 1920
HOWELL, LESLIE DILLON. Valuation Dept., C., M. & St. P. R. R., 509 Le Moyne Bldg., Chicago, Ill.		Jan. 19, 1920
KENNEY, HARRY WILLEY. Design Draftsman and Chf. of Squad, Bureau of Yards and Docks, Navy Dept., 1526 Seventeenth St., N. W., Washington, D. C.		Jan. 19, 1920

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
KING, TAO. Res. Member, Comm. on Railway Technics, Ministry of Communications, 33 Tou Fa Hutung, West City, Peking, China	Jun. Assoc. M.	May 28, 1912 Nov. 25, 1919
MACARTNEY, THOMAS WAKEFIELD. County Drainage Engr., Yakima County, Yakima, Wash.		Jan. 19, 1920
MACSHEFFRAY, FRANK ALBERT. Works Engr., Fred T. Ley & Co., Inc., 857 Commonwealth Ave., Boston, Mass.		Sept. 9, 1919
MCFERRON, CLARENCE WILLIAM. Chf. Engr., Shell Creek Project of Sand Springs Home, Box 411 (Res., 803 South Quaker), Tulsa, Okla.		Jan. 19, 1920
MAIL, EUGENE FREDERICK. City Engr., Robinson, Ill.	Jun. Assoc. M.	Mar. 4, 1913 Jan. 19, 1920
MARTIN, JAMES MCQUEEN. Highway Engr., Williamsburg County, Kingstree, S. C.		Jan. 19, 1920
NOETZLI, ALFRED ADOLPH. Chf. Engr., Hydro-Elec. Power Developments, Beckman & Linden Eng. Corporation, 415 Balboa Bldg., San Francisco, Cal.		Nov. 25, 1919
PARTRIDGE, JOHN FREDERICK. 3455 Pacific Ave., San Francisco, Cal.	Jun. Assoc. M.	Feb. 4, 1913 Jan. 19, 1920
PERKINS, ROSCOE, JR. Cornwells Heights, Pa.	Jun. Assoc. M.	Mar. 12, 1918 Jan. 19, 1920
PILLSBURY, ARTHUR CLIFTON. 312 Los Angeles Investment Bldg., Los Angeles, Cal.		Jan. 19, 1920
REASONER, RICHARD BARKLEY. Div. Engr., Ore. Short Line R. R., Utah Div., O. S. L. Depot, Pocatello, Idaho.		Jan. 19, 1920
WARNECKE, WILLIAM HENRY. Capt., Engrs., U. S. A., Engineer School, Camp A. A. Humphreys, Va.		Jan. 19, 1920
WHIPPLE, JOHN BLAINE. Asst. Engr., Dept. of Highways, State of New York, 60 Beacon St., Newburgh, N. Y.		Nov. 25, 1919
WHITE, JOHN ALOYSIUS. Engr., Constr. Dept., International Motors Co., 849 North 5th St., Allentown, Pa.		Oct. 14, 1919
WINN, THOMAS EARLE, JR. Box 81, Quincy, Fla.		Jan. 19, 1920

JUNIORS

ALVAREZ DE URRUTIA, ARMANDO MANUEL. Eng. Draftsman, The Snare & Triest Co., 561 Cerro St., Havana, Cuba.	Jan. 19, 1920
BUTLER, ALBAN FRANCIS. 256 Kelton Ave., Columbus, Ohio.	Sept. 9, 1919
HSIEH, ERNEST SHENGTSU. 520 Myburch Rd., Shanghai, China.	Sept. 9, 1919
MCCLELLAND, GEORGE W. 4124 Warwick Boulevard, Kansas City, Mo.	April 14, 1919
WATSON, LEON HEATHMAN. Box 475, Ponca City, Okla.	Nov. 25, 1919

REINSTATEMENTS

MEMBERS	Date of Reinstatement.
FENN, ROBERT WILLSON	Feb. 10, 1920

RESIGNATIONS

MEMBERS	Date of Resignation.
HARRISON, CHRISTOPHER	Dec. 31, 1919

ASSOCIATE MEMBERS	
BLAYLOCK, JOHN CHARLES	Dec. 31, 1919
DAVIS, ROBERT MENEES	Dec. 31, 1919

DEATHS

FORD, THEODORE BOYDEN. Elected Member, December 6th, 1905; died Feb. 2d, 1920.

GREGORY, CHARLES EMERSON. Elected Junior October 6th, 1896; Associate Member, March 6th, 1901; Member, June 19th, 1918; died February 21st, 1920.

LOOMIS, THOMAS HOOKER. Elected Member, January 7th, 1903; died February 11th, 1920.

LUPFER, ALEXANDER MCCLURE. Elected Member, November 1st, 1905; died February 3d, 1920.

MORRILL, GEORGE SULLIVAN. Elected Member, March 2d, 1887; died February 9th, 1920.

PALMER, RAY ROLPH. Elected Associate Member, October 10th, 1916; died December 25th, 1919.

PRATT, ROBERT WINTHROP. Elected Member, June 6th, 1911; died February 2d, 1920.

SMITH, EDWIN FOSTER. Elected Member, June 5th, 1895; died January 26th, 1920.

THOMPSON, SAMUEL CLARENCE. Elected Member, February 6th, 1889; died February 28th, 1920.

WRIGHT, WILLIS BENTON. Elected Member, November 3d, 1897; died November 16th, 1919.

Total Membership of the Society, March 4th, 1920, 9 381

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(February 1st to March 1st, 1920)

NOTE.—*This list is published for the purpose of placing before the members of this Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Journal,* Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Journal,* Eng. Inst. of Canada, Montreal, Que., Canada.
(6) *Journal,* Am. Inst. of Archts., Washington, D. C., 50c.
(7) *Gesundheits Ingenieur,* Munich, Germany.
(8) *Stevens Indicator,* Hoboken, N. J., 50c.
(9) *Industrial Management,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News-Record,* New York City, 15c.
(15) *Railway Age,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Electric Railway Journal,* New York City, 10c.
(18) *Railway Review,* Chicago, Ill., 15c.
(19) *Scientific American Monthly,* New York City, 10c.
(20) *Iron Age,* New York City, 20c.
(21) *Railway Engineer,* London, England, 1s. 2d.
(22) *Iron and Coal Trades Review,* London, England, 6d.
(24) *American Gas Engineering Journal,* New York City, 10c.
(25) *Railway Mechanical Engineer,* New York City, 20c.
(26) *Electrical Review,* London, England, 4d.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Royal Soc. of Arts, London, England, 6d.
(32) *Mémoires et Compte Rendu des Travaux,* Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil,* Paris, France, 1 fr.
(36) *Cornell Civil Engineer,* Ithaca, N. Y.
(40) *Zentralblatt der Bauverwaltung,* Berlin, Germany, 60 pfg.
(41) *Elektrotechnische Zeitschrift,* Berlin, Germany.
(42) *Journal,* Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées,* Paris, France.
(45) *Coal Age,* New York City, 15c.
(46) *Scientific American,* New York City, 15c.
(47) *Mechanical Engineer,* Manchester, England, 3d.
(48) *Zeitschrift,* Verein Deutscher Ingenieure, Berlin, Germany, 1, 60 m.
(49) *Zeitschrift für Bauwesen,* Berlin, Germany.
(50) *Stahl und Eisen,* Düsseldorf, Germany.
(53) *Zeitschrift,* Oesterreichischer Ingenieur und Architekten-Verein, Vienna, Austria, 70h.
(54) *Transactions,* Am. Soc. C. E., New York City, $16.
(55) *Mechanical Engineering:* Journal, Am. Soc. M. E., New York City, 35c.
(56) *Transactions,* Am. Inst. Min. and Metallurgical Engrs., New York City, $6.
(57) *Colliery Guardian,* London, England, 5d.
(58) *Proceedings,* Engrs.' Soc. of W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings,* American Water Works Assoc., Troy, N. Y.
(60) *Municipal and County Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Drop Forger,* Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 10c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Gas Journal,* London, England, 6d.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(69) *Eisenbau,* Leipzig, Germany.

(71) *Journal*, Iron and Steel Inst., London, England.
(71a) *Carnegie Scholarship Memoirs*, Iron and Steel Inst., London, England.
(72) *American Machinist*, New York City, 15c.
(73) *Electrician*, London, England, 18c.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(77) *Journal*, Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen*, Vienna, Austria, 1, 50m.
(80) *Tonindustrie Zeitung*, Berlin, Germany.
(83) *Gas Age*, New York City, 15c.
(85) *Proceedings*, Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering and Contracting*, Chicago, Ill., 10c.
(87) *Railway Maintenance Engineer*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings*, Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions*, Inst. of Naval Archts., London, England.
(91) *Transactions*, Soc. of Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin*, Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie*, Paris, France, 4 fr. 50.
(96) *Canadian Engineer*, Toronto, Ont., Canada, 10c.
(98) *Journal*, Engrs. Soc. of Pa., Harrisburg, Pa., 30c.
(99) *Proceedings*, Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs*, Corps of Engrs., U. S. A., Washington, D. C., 50c.
(103) *Mining and Scientific Press*, San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer*, London, England, 6d.
(105) *Chemical and Metallurgical Engineering*, New York City, 25c.
(106) *Transactions*, Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung*, Zürich, Switzerland.
(109) *Journal*, Boston Soc. C. E., Boston, Mass., 50c.
(111) *Journal of Electricity*, San Francisco, Cal., 25c.
(113) *Proceedings*, Am. Wood Preservers' Assoc., Baltimore, Md.
(114) *Journal*, Institution of Municipal and County Engineers, London, England, 1s. 6d.
(115) *Journal*, Engrs.' Club of St. Louis, St. Louis, Mo., 35c.
(116) *Blast Furnace and Steel Plant*, Pittsburgh, Pa., 15c.
(117) *Engineering World*, Chicago, Ill.
(118) *Times Engineering Supplement*, London, England, 2d.
(119) *Landscape Architecture*, Harrisburg, Pa., 50c.
(120) *Automotive Industries*, New York City, 15c.
(121) *Proceedings*, Am. Concrete Inst., Boston, Mass.

LIST OF ARTICLES

Bridges.

Platte River Bridge Reconstruction, Rock Island Lines.* (13) Feb. 5.
Primary Stress-Determination in Space Frames.* R. V. Southwell. (11) Feb. 6.
Longest Concrete Arch Span Being Built at Minneapolis.* (13) Feb. 12.
A Stone Beam Bridge in China Sixty Years Old.* Donald F. McLeod. (13) Feb. 12.
Application of Dewey System for Numbering County Bridges. Harry F. Harris. (From Paper read before New Jersey County Engrs.' Assoc.) (86) Feb. 25.
Longest Concrete Girder Bridge is Built in California.* (13) Feb. 26.
Le nouveau réglement français pour le calcul et les épreuves des ponts métalliques. H. Hartmann. (107) Dec. 27, 1919.
Hebung und Wiederherstellung zweier gesprengter Eisenbahnbrücken.* A. Dürbeck. (69) Mar., 1919.
Die Günstigste Form Eiserner Zweigelenkbrückenbogen ohne Zugband.* Alfred Berrer. (69) June, 1919.
Heben und Verschieben einer Eisernen Strassenbrücke.* L. Altpeter. (69) June, 1919.
Eisen und Eisenbeton im Brückenbau. Schaper. (69) Aug., 1919.
Die Wiederherstellung Zerstörter Steinbrücken in Frankreich. (78) Aug. 4, 1919.
Baukunst und Ingenieurästhetik.* E. Wehner. (69) Sept., 1919.

Electrical.

Carbon Arcs for Searchlights.* C. C. Paterson and others. (77) Jan.
The Short Tungsten Filament as a Source of Light and Electrons.* G. Stead. (77) Jan.
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* Illustrated.

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

ARCHED DAMS.*

By B. A. Smith,† M. Am. Soc. C. E.

Synopsis.

A solution of the problem of arch dam analysis is offered which, although not free from objection, avoids the obvious defects of the ordinary cylinder theory. These defects are, that, by the latter theory, the arch thrust is a maximum at the base of the dam where, as a matter of fact, it must vanish and that it vanishes at the crest where, in any ordinary case, the deflection is greatest and as a consequence the stress due to the arch thrust must be a maximum. Two cases are dealt with: (1) A complete cylindrical dam or tank of uniform thickness throughout; (2) a complete cylindrical dam or tank of uniformly varying thickness from crest to base. The mathematical investigation of these cases is given in Appendix 1. Case 1 is found to be included in case 2.

It is shown in Appendix 2 that, provided we neglect the twist in the material arising from the base being fixed while the cylinder is deformed by the water pressure, we can use the solutions obtained for the complete cylinder, as an approximation to the solution for the deepest part of a dam built in a valley of any form provided that we replace the ordinary Young's Modulus for the horizontal thrusts by a modulus two-thirds as great. The effect of temperature is con-

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* This paper will not be presented for discussion at any meeting of the Society, but written communications on the subject are invited for subsequent publication in *Proceedings* and with the paper in *Transactions*.

† Melbourne, Victoria, Australia.

sidered, and it is demonstrated by a numerical example in Appendix 4 that the stresses due to variations of temperature may be considerably greater than those due to the water pressure.

Tables of Michell's functions are given which enable the solution of any problem on the design of arched dams of wedge shaped cross section, the upstream surface being a vertical cylinder of constant radius, to be made. The chief labor involved is the solution of a set of four simultaneous equations to determine four arbitrary constants which enter into the expression for the displacement of any point in the vertical generators of the cylinders, but with a six or eight figure calculating machine this can be done in about an hour.

A remarkable feature of Michell's functions is the balance which subsists between them leading to very small resultants when the functions are combined in the course of the work. This renders it necessary to exercise care in using them; in particular it will be found necessary to retain six or seven significant figures in the arbitrary constants, otherwise we shall be led to quite erroneous results. A perusal of the numerical work in Appendix 3 will show this clearly.

Although at first sight the tables appear to be limited to a height of 30 ft., it will be found that this is not really the case, the numbers 1 to 30 in the tables are merely like the ordinary numbers in a table of logarithms, and the height may be 200 ft., or even more. The limitation of the investigation to the two cases of uniform thickness and a truncated wedge shaped cross section will, it is hoped, be viewed with leniency, when account is taken of the somewhat laborious nature of the investigation even in these two comparatively simple types of arched dams.

The Cylinder Theory.

A recent paper by H. Hawgood, M. Am. Soc. C. E., on the Huacal Dam, Sonora, Mexico,* indicates that the subject of the design of arched dams is not yet exhausted. The usual procedure hitherto has been to assume that the arch thrust is given by the expression†

$$T = p\ R$$

* *Transactions*, Am. Soc. C. E., Vol. LXXVIII (1915), p. 564.

† *Transactions*, Am. Soc. C. E., Vol. LXXVIII (1915), Table 1, p. 567.

in which

p = the pressure in pounds per square foot at the section considered;

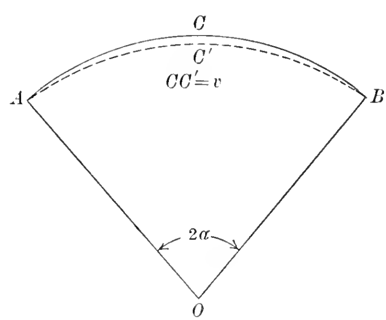
R = the radius of the upstream face, in feet;

T = the arch thrust in pounds per foot height of the dam at the given section.

It is, however, generally recognized by engineers that this expression can only give the thrust at points so far above the base that the arch can deflect sufficiently to allow the material to come into compression. In the case of the Huacal Dam, for example, the radial displacement near the base would have to be of the order of $\frac{1}{8}$ in. in order to allow the calculated arch thrust to exist. An elastic movement of the foundation rock of this magnitude is hardly conceivable. The assumption that the base is rigidly fixed is probably a much nearer approximation to the actual conditions.

Proposed Modification of the Cylinder Theory.

The present paper is an attempt to carry the approximation of the cylinder theory a step farther by taking account of the shear across a horizontal plane and the corresponding bending moment about a horizontal tangent to the cylinder.



PLAN OF SEGMENTAL DAM

Fig. 1.

First, consider a complete cylinder symmetrically deformed so that the displacement of every point is radial. It is clear that, in this case, there will be no shear across vertical axial planes, and as a consequence there will be no bending moment about the vertical generators; that is, in the case of the complete cylinder, bending as a horizontal arch does not occur.

Segmental Dams.

Next consider a segment of the cylinder $A\ C\ B$, Fig. 1, between two vertical generators at A and B respectively, subtending an angle $A\ O\ B = 2\ \alpha$ at the axis O, and suppose this segment is free to slide on the base and is merely supported at the ends A and B so that the bending moment vanishes at each of these ends. Then,

assuming that the bending moment vanishes throughout and that the segment is subjected to a uniform compressive stress (arch thrust) throughout its length so that the elastic compression, f, is constant throughout, the segment deforms to the shape $A\ C'\ B$ and, as is shown in Appendix 2, the displacement $C\ C'$ $(= v)$ of the centre of the segment is given by

$$v = \frac{f\ R\ \alpha\ (1 - \cos.\ \alpha)}{\sin.\ \alpha - \alpha \cos.\ \alpha}$$

where

$f =$ the elastic compression of the material; that is, the ratio of the contraction of any given length under compression to the original length of that portion;

$R =$ the radius of the cylinder;

$2\alpha =$ the angle $A\ O\ B$.

If $2\ \alpha$ is less than $\frac{2\ \pi}{3}$, or $120°$, there can be written, approximately,

$$v = \frac{3}{2}\ f\ R$$

which is independent of α.

This means that the radial displacement v at C, the centre of the segment $A\ C\ B$, supposed to be fixed in position at the abutments A and B, though free to turn about these points, is the same as it would have been if $A\ C\ B$ formed part of a complete cylinder, subject to the same stress, whose Young's Modulus E had a value two-thirds of that of the actual material.

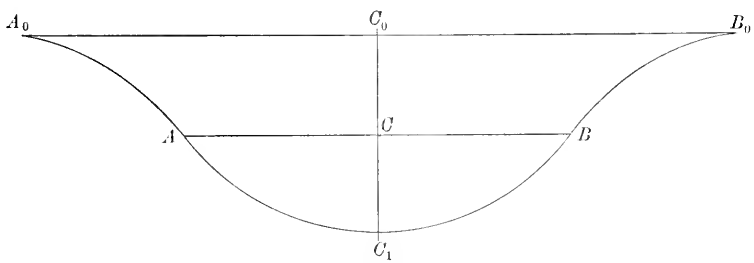
It may be mentioned, to anticipate the objection being taken, that unless extraordinary precautions are taken to fix in direction the ends of the arch, A and B, there will be deflections at these points which will correspond very nearly to the deflections due to no bending moment at A and B.

Dams Constructed in Valleys of Any Profile.

In order to pass from the ideal case to the actual one, namely, a dam built in a valley of any profile, the twist in the surface which occurs when the base, instead of being free to slide, is fixed throughout is neglected. If this is done, $A\ C\ B$, Fig. 2, may be regarded as any horizontal section of a dam of which $A_0\ C_0\ B_0$ is the crest and $C_0\ C\ C_1$

the central vertical generator so that A_0 A C_1 B B_0 is the profile of the valley which, under the conditions premised, may be of any shape whatever, so long as it is approximately symmetrical. As is shown in Appendix 2, and subject to the limitations there given, the radial displacement of any point C of the central vertical generator C_0 C C_1 will then be the same as if that generator formed part of a complete cylinder the value of Young's Modulus for which is two-thirds of that of the actual material of the dam.

The solution obtained for the complete cylinder is thus applicable (subject to the reservations mentioned above) to the case of any ordinary arched dam, the value of the Young's Modulus being taken as two-thirds of its value for the material of which the dam is built.



ELEVATION OF SEGMENTAL DAM IN VALLEY

FIG. 2.

LIMITATION OF SOLUTIONS TO TWO TYPES OF DAM.

Two cases are here considered: (1), a cylindrical dam or tank of uniform thickness throughout; (2), a cylindrical dam of finite crest width and of uniformly varying thickness from crest to base.

The difficulty of obtaining a solution of the equation of equilibrium of the material in other cases must be pleaded in excuse for no attempt being made at a general solution applicable to dams of any cross section; the simple cases considered are troublesome enough. The solution of the first case, the cylindrical dam of uniform thickness, results quite simply in terms of known functions, circular and hyperbolic. The solution of the second case is obtained in series. Four different series each of which satisfies the equation of equilibrium are required; these are given in algebraic form, together with tables for the values of each of the functions and their first three derivatives, which are all required to satisfy the boundary conditions at the

crest and at the base of the dam. These functions will be referred to as Michell's* functions.

It is shown that the solution of the fundamental equation can be formally expressed in terms of Bessel's functions, but as the functions involved have complex arguments it is considered preferable to leave the solution in terms of Michell's functions, which involve only a real argument. The solution in terms of Bessel's functions, however, is useful as it permits the extension of the tables by using the "semiconvergent" expressions, and this makes it possible to deduce the solution for the uniform dam from the case where the thickness is variable.

An equation corresponding to the fundamental equation of case (2) for a particular case, namely when the section is a triangle with its crest at the water level, is given by H. Lorenz†, but as this solution is of very limited application and as only two solutions of the four series of the fundamental equation are given, and then only in series form, it cannot be regarded as a complete solution of the problem.

The solution obtained for case (1) shows that the bending moment rapidly dies out as we leave the base of a dam or tank of uniform thickness, whether the base is fixed in direction or merely simply supported, and that at a height above the base equal to three or four times the thickness of the dam the ordinary cylinder formula $T = p\ R$ applies quite nearly enough. This statement must not be taken to indicate that the bending moment near the base can be disregarded, for this cannot be done altogether, but it shows the great assistance given by the arch in supporting the load on the dam.

Temperature Effect.

The effect of temperature changes on the stresses is considered, and it is shown that a very moderate range of temperature will give rise to stresses considerably greater than those due to the water pressure. As a consequence, it appears that, if practicable, a concrete dam should be built at a time when the temperature is well below the mean temperature of the locality, for if this is done the effect of a rise of temperature is to enhance the arch effect, and it may even cause the dam to deflect upstream against the water pressure. This

* These functions are here published for the first time.

† "Lehrbuch der Technichen Physik", Vol. IV, p. 618.

was found to happen in the case of the Wooling Dam, to which these calculations were first applied.

A similar phenomenon is suggested by the observations of the deflections of the Barren Jack Arch Dam shown in Fig. 6 of the paper* by Mr. Hawgood.

THE ARGUMENTS OF MICHELL'S FUNCTIONS.

Attention should be called to the fact that the arguments x in the tables of Michell's functions are not actual heights but are mere numbers like the arguments in a table of logarithms. The relation between x and the actual depth z below the origin, which is taken to be at the intersection of the upstream and downstream faces of the dam, is given by

$$z = k\,x$$

where

$$k^2 = \frac{1}{12} C^2 R^2 \frac{E_1}{E_0}$$

in which

C = the tangent of the angle between the upstream and downstream faces of the dam, in a vertical axial section;

R = the radius of the cylindrical upstream face;

E_1 = Young's Modulus for the vertical forces;

E_0 = Young's Modulus for the arch thrust.

In the case of the complete cylinder, E is the ordinary value of Young's Modulus. In the case of the segmental dam E_0 becomes $\frac{2}{3}\,E_0$. The value of E_1 depends on the vertical reinforcement. If p is the ratio of area of steel reinforcement to concrete, then

$$E_1 = E\,(1 + 15\,p)$$

where E is the ordinary Young's Modulus for concrete for the vertical reinforcement. For steel $E_1 = 30 \times 10^6$ lb. per sq. in. $= 15 \times E$.

For example, if $p_1 = 2\%$ and $E = 2 \times 10^6$ lb. per sq. in. and $p_0 = 1\ \%$ for the horizontal reinforcement

$$E_1 = 2 \times 10^6\ \ (1 + 15 \times 0.02) = 2.6 \times 10^6$$
$$E_0 = 2 \times 10^6\ \ (1 + 15 \times 0.01) = 2.3 \times 10^6$$

The fact that the dam is segmental does not affect E_1, in calculating which the ordinary Young's Modulus is used. Suppose, for

* *Transactions*, Am. Soc. C. E., Vol. LXXVIII (1915), p. 578.

example, a segmental dam of 200 ft. radius with upstream face vertical and the batter of the downstream face 1 in 6, so that $c = \frac{1}{6}$, and with 2% vertical reinforcement and no horizontal reinforcement. There is obtained

$$E_1 = 2.6 \times 10^6 \text{ lb. per sq. in.}$$
$$E_0 = 2.0 \times 10^6 \text{ lb. per sq. in.}$$

and since the dam is segmental, replace E_0 by $\frac{2}{3}$ E_0, *i. e.*, by $\frac{2}{3} \times 2.0 \times 10^6$, and

$$k = \frac{1}{6} \times 200 \times \sqrt{\frac{1}{12} \times \frac{2.6 \times 10^6}{\frac{2}{3} \times 2.0 \times 10^6}}$$

$$= \frac{200}{6} \times \sqrt{\frac{1}{12} \times \frac{3}{2} \times 1.3}$$

$$= 13.5 \text{ say.}$$

Now suppose that the crest width of the dam is 4 ft. 6 in. and its depth 202 ft. 6 in. (corresponding to a dam about 200 ft. deep). Since the batter is 1 in 6, the origin is at a height $6 \times 4.5 = 27$ ft. above the crest. At crest level $z = z_0 = 27$ ft. and

$$z = k\,x = 13.5\,x$$

hence
$$x_0 = \frac{27}{13.5} = 2.0$$

At the base, $z = z_1 = 27 + 202.5 = 229.5$ ft., and therefore

$$x_1 = \frac{229.5}{13.5} = 17.0$$

and the tabular values to be used are those corresponding to $x = 2$ at the crest, and to $x = 17$ at the base.

The range covered by the tables will be found sufficient for most practical purposes. If it is desired to go beyond the tables, it is suggested that the semiconvergent expressions be used in preference to the series, which become unmanageable at about $x = 30$.

Proposed Method of Design, Using Michell's Functions.

It is suggested that as a convenient method of design the following procedure be adopted:

1.—Determine the maximum flood height above the crest of the dam $= h$ say.

2.—Assume that the pressure at any depth d below the crest is

$$p = w\,(d + h)$$

where w = 62.5 lb. per sq. ft. per foot depth (which is of course the same as the weight of 1 cu. ft. of water).

h = height of flood level above crest, in feet.

d = depth of the given point below the crest, in feet.

This will give pressures near the crest slightly in excess of the actual pressures, but this error may be disregarded.

3.—Fix the maximum compressive stress (arch thrust) allowable in the material $= K$ lb. per sq. ft., say and determine the corresponding thickness of the dam by the ordinary cylinder formula

$$T = p\,R$$

where T = the resultant ring thrust per foot height.

p = the pressure in pounds per square foot as given above.

R = the radius of the arch.

The smaller R is, of course, the smaller T will be and the more effective the arch action. If t is the thickness of the arch in feet, then

$$T = k\,t = p\,R$$

4.—Fix the minimum safe thickness at the crest of the dam in view of possible injury by floating timber or other bodies, say t_0 ft. Then, if the thickness is to vary uniformly from t_0 at the crest to t_1 ft. at the base in the depth D.

$$c = \frac{t_1 - t_0}{D}$$

5.—Decide whether the base of the dam is to be rigidly built into the foundation rock by means of steel reinforcing bars sunk well into the rock below, that is, encastrêe, or whether the base is to be simply supported by the pressure of the rock downstream against the downstream face of the dam. The former method will ensure a watertight base but can only be adopted when the rock is quite solid. If the latter method is adopted, observe that the vertical generators of the cylinder will deflect downstream under the water pressure, and cause the base of the dam to lift off its seat on the upstream side causing liability to leakage under the seat which must be provided against by layers of clay and sand or otherwise according to judgment. If it is decided

that the base shall be encastrée, the conditions to be satisfied at the base are:

(1), the radial displacement must be zero, that is, $u = 0$;

(2), the generating lines of the cylinder must remain fixed in direction, *i. e.*, $\frac{d\,u}{d\,x} = 0$.

If the base is simply supported, the bending moment at the base vanishes and, as before, the radial displacement must vanish, that is, (1) $u = 0$; and (2) $\frac{d^2\,u}{d\,x^2} = 0$. At the crest the boundary conditions are the same in either case, namely the bending moment and the shear, both of which are due to the action of the material above the section or that below it, must vanish, since there is no material above the crest, that is, at the crest

$$\frac{d^2\,u}{d\,x^2} = \frac{d^3\,u}{d\,x^3} = 0$$

These four conditions give rise to four equations among the four arbitrary constants which enter into the solution. When these four constants are determined it is possible, by means of the tables, to find the displacement and consequently the arch thrust at a series of points, also the bending moment, the shear and, if necessary, the deflection, although this is of no interest to us except at the base of the dam. When the bending moments have been determined at the points corresponding to the integral values of x given in the tables, a smooth curve can be drawn through these points to give nearly enough the bending moment at any point of the dam. The necessary reinforcement can then be found by the usual rules.

A remarkable feature of the solution is the smallness of the resulting bending moment compared with the magnitude of the four component terms which contribute to it. An example of the numerical calculations is given in Appendix 3.

6.—Determine the temperature range to which the dam will be subject and estimate as nearly as practicable the amounts by which the maximum and minimum temperatures vary from the mean temperature during construction. Let e = the coefficient of expansion of the concrete, or 0.0000055 per degree Fahr., say (about $\frac{3}{8}$ in. per chain for 100° Fahr., as against about $\frac{1}{2}$ in. per chain for 100° Fahr. for steel). For satisfactory construction a nickel-iron alloy having

the same coefficient of expansion as concrete, is a desideratum, as this would minimize the internal stresses due to unequal expansion and contraction of the iron and the concrete. Suppose θ is the maximum difference of temperature in degrees Fahr. to be expected from the mean temperature observed during construction, regarded as plus if above this mean and minus if below it. As before, let R be the radius of the dam. If now the dam, supposed empty, is free to expand throughout, the displacement at any point will be, in feet,

$$v = - e \theta R$$

the minus sign being used to indicate that the points considered move *away* from the axis. If, after this expansion, the base is now forcibly displaced toward the axis through the distance v, the generators being held fixed in direction $\left(\frac{d u}{d x} = 0\right)$ if the base is encastrée, or allowed to deflect so that the bending moment vanishes $\left(\frac{d^2 u}{d x^2} = 0\right)$ if the base is simply supported. In either case, the conditions at the crest are that the bending moment and the shear both vanish; that is,

$$\frac{d^2 u}{d x^2} = \frac{d^3 u}{d x^3} = 0$$

If these four conditions are satisfied the dam is clearly in the same condition as if the base had been fixed while the temperature rose by the amount θ.

This again gives rise to four simultaneous equations for four new arbitrary constants. The coefficients on the left-hand side of the equations are the same as those which were used in determining the constants for the water pressure equations, so that the labor of the solutions is lightened in this case. The stresses due to the temperature are of course to be superposed on those due to the water pressure. An example of the numerical work is given in Appendix 4.

APPENDIX I.

INVESTIGATION OF STRESSES IN CYLINDERS

Explanation of Symbols.

Consider the origin O to be at the topwater level (flood level) of the dam in cases where the thickness is uniform and at the intersection of the upstream and downstream faces when the dam is of triangular section, and consider the axis of Z vertical downward. Let

T = ring thrust per unit depth at any point P at depth z below the origin, reckoned positive when compression;

F = the resultant traction or shearing force per unit length along the dam at P exerted by the material above P on that below P, reckoned positive when this traction is exerted toward the axis of the cylinder;

M = the couple about a horizontal tangent at P per unit length of the dam, reckoned positive when the bending tends to make the generators of the cylinder *concave* toward its axis.

u = the displacement, along the radius, of a point P on the cylindrical surface, reckoned positive when toward the axis of the cylinder. (Strictly speaking, these should refer throughout to the neutral surface, but it is simpler to deal with the upstream cylindrical surface. So long as the dam is thin the error is not worth considering);

$\frac{du}{dz}$ = the inclination of the generator to the vertical, reckoned positive when the lower part is inclined toward the axis;

$\frac{d^2u}{dz^2}$ = the curvature of the generator at P after strain, reckoned positive when the concavity is toward the axis of the cylinder;

t = the thickness of the dam at P;

I = the moment of inertia of a horizontal section of the dam at P, of unit length along the cylinder, or $I = \frac{1}{12} t^3$;

E_0 = Young's Modulus for the horizontal direction. If p_0 is the ratio of the area of horizontal reinforcement to the area of the concrete in a vertical section, assuming that Young's Modulus for steel is 15 times as great as for

ordinary concrete for which it has the value E, then $E_0 = E\ (1 + 15p_0)$;

E_1 = Young's Modulus for the vertical direction. If p_1 is the ratio of the area of vertical reinforcement to the area of concrete in a horizontal section, then as above $E_1 = E\ (1 + 15p_1)$;

C_1 = the rigidity of a vertical slab of unit length along the dam; neglecting the change of curvature in the horizontal plane, $C_1 = E_1 I = \frac{1}{12}\ E_1\ t^3$;

p = the water pressure in pounds per square foot at $P = w\ (d + h)$ where w is the weight of 1 cu. ft. of water = 62.5 lb., d the depth of the point P below the crest of the dam and h the flood height;

R = the radius of the cylindrical upstream surface of the dam;

c = the tangent of the angle between the upstream and downstream faces.

a = a factor connecting vertical distances with the arguments of Michell's functions defined by Equations (31) and (33) following:

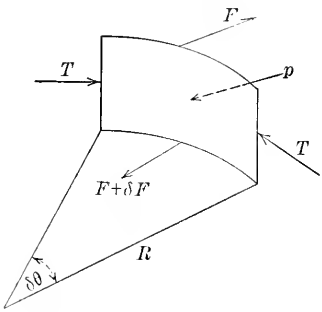
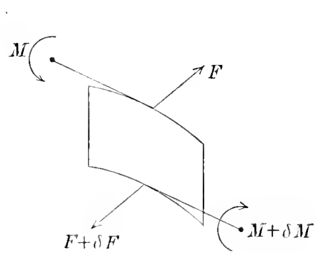


DIAGRAM OF FORCES ON AN ELEMENT

FIG. 3.



SHEARING FORCES AND COUPLES ON AN ELEMENT

FIG. 4.

Equations of Equilibrium

Considering the equilibrium of a small curved rectangular element of height δz and width $R\ \delta\ \theta$, there is obtained (see Figs. 3 and 4), for the forces

$$(F + \delta\ F)\ R\ \delta\ \theta - F\ R\ \delta\ \theta - T\ \delta\ z\ \delta\ \theta + p\ R\ \delta\ \theta\ \delta\ z = 0$$

and for the couples

$$(M + \delta\ M)\ R\ \delta\ \theta - M\ R\ \delta\ \theta + F\ R\ \delta\ \theta\ \delta\ z = 0$$

Hence, dividing out by $R \; \delta \; \theta \; \delta \; z$

$$\frac{d\,F}{d\,z} - \frac{T}{R} + p = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\frac{d\,M}{d\,z} + F = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

and for the equation connecting the bending moment with the change of curvature, as usual

$$M = C_1 \frac{d^2\,u}{d\,z^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

neglecting the bending about the vertical generators, which is very small.

Again, the equation connecting the displacement with the ring thrust in the complete cylinder is

$$T = \frac{E_0\,t}{R} \times u \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

and in the case of a segmental dam (see Appendix II),

$$T = \frac{2}{3}\,\frac{E_0\,t}{R} \times u \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Eliminating F between Equations (1) and (2)

$$\frac{d^2\,M}{d\,z^2} + \frac{T}{R} = p \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Substituting for M from Equation (3) and for T from Equation (4), for the case of the complete cylinder

$$\frac{d^2}{d\,z^2}\left(C_1\,\frac{d^2\,u}{d\,z^2}\right) + \frac{E_0}{R^2}\,.\,t\,u = p \ldots\ldots\ldots\ldots\ldots (7)$$

and in the case of the segmental dam

$$\frac{d^2}{d\,z^2}\left(C_1\,\frac{d^2\,u}{d\,z^2}\right) + \frac{2}{3}\,.\,\frac{E_0}{R^2}\,t\,u = p \ldots\ldots\ldots\ldots (8)$$

Equations (7) and (8) are identical except that in (8) the value $\frac{2}{3}\,E_0$ is used instead of E_0; that is, for the horizontal stresses a modulus equal to two-thirds of the ordinary Young's Modulus is applied.

CASE I.—DAM OF UNIFORM THICKNESS.

For the case of a dam of uniform thickness, t is constant, so that Equation (7) becomes

$$\frac{d^4\,u}{d\,z^4} + \frac{E_0\,t}{C_1\,R^2}\,u = \frac{p}{C_1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

or calling

$$\mu^4 = \frac{E_0\,t}{C_1\,R^2} = 12\,\frac{E_0}{E_1}\,\frac{1}{t^2\,R^2}$$

Equation (9) may be written in the form

$$\frac{d^4\,u}{d\,z^4} + \mu^4\,u = \frac{p}{C_1} \qquad \text{(10)}$$

Now if p involves no power of z above cubes (in this case $p = w\,z$, so that it only involves the first power of z), the particular integral of Equation (10) is

$$u = \frac{p}{\mu^4\,C_1} = \frac{p\,R^2}{E_0\,t} = \frac{w\,R^2}{E_0\,t}\,z \qquad \text{(11)}$$

for this makes $\frac{d^4\,u}{d\,z^4} = 0$ and, therefore, satisfies Equation (10).

There must now be found a solution of

$$\frac{d^4\,u}{d\,z^4} + \mu^4\,u = 0 \qquad \text{(12)}$$

involving four arbitrary constants (the complementary function).

The auxiliary equation is

$$m^4 + \mu^4 = 0 \qquad \text{(13)}$$

from which

$$m^2 = \pm\,\mu^2\,\sqrt{-1} = \pm\,i\,\mu^2$$

hence

$$m = \pm\,\mu\,\sqrt{\pm\,i} = \pm\,\frac{\mu}{\sqrt{2}}\,(1 \pm i)$$

the four roots of Equation (13) are therefore

$$m_1 = +\,\frac{\mu}{\sqrt{2}}\,(1 + i)$$

$$m_2 = -\,\frac{\mu}{\sqrt{2}}\,(1 + i)$$

$$m_3 = +\,\frac{\mu}{\sqrt{2}}\,(1 - i)$$

$$m_4 = -\,\frac{\mu}{\sqrt{2}}\,(1 - i)$$

so that

$$m_1^{\,4} = m_2^{\,4} = m_3^{\,4} = m_4^{\,4} = -\,\mu^4 \qquad \text{(14)}$$

The complementary function is therefore

$$u = A^1 e^{m_1 z} + B^1 e^{m_2 z} + C^1 e^{m_3 z} + D^1 e^{m_4 z} \quad \ldots\ldots\ldots (15)$$

This is easily verified by differentiating Equation (15) four times

$$\frac{d^4 u}{d z^4} = m_1^4 A^1 e^{m_1 z} + m_2^4 B^1 e^{m_2 z} + m_3^4 C^1 e^{m_3 z} + m_4^4 D^1 e^{m_4 z}$$

$$= - \mu^4 [A^1 e^{m_1 z} + B^1 e^{m_2 z} + C^1 e^{m_3 z} + D^1 e^{m_4 z}]$$

$$= - \mu^4 \times u$$

So that

$$\frac{d^4 u}{d z^4} + \mu^4 u = 0$$

Since

$$e^{i \frac{\mu z}{\sqrt{2}}} = \cos. \frac{\mu z}{\sqrt{2}} + i \sin. \frac{\mu z}{\sqrt{2}}$$

and

$$e^{-i \frac{\mu z}{\sqrt{2}}} = \cos. \frac{\mu z}{\sqrt{2}} - i \sin. \frac{\mu z}{\sqrt{2}}$$

Now, Equation (15) may be written

$$u = e^{\frac{\mu z}{\sqrt{2}}} \left[A^1 \left(\cos. \frac{\mu z}{\sqrt{2}} + i \sin. \frac{\mu z}{\sqrt{2}} \right) + C^1 \left(\cos. \frac{\mu z}{\sqrt{2}} - i \sin. \frac{\mu z}{\sqrt{2}} \right) \right]$$

$$+ e^{-\frac{\mu z}{\sqrt{2}}} \left[B^1 \left(\cos. \frac{\mu z}{\sqrt{2}} - i \sin. \frac{\mu z}{\sqrt{2}} \right) + D^1 \left(\cos. \frac{\mu z}{\sqrt{2}} + i \sin. \frac{\mu z}{\sqrt{2}} \right) \right]$$

$$= e^{\frac{\mu z}{\sqrt{2}}} \left[(A^1 + C^1) \cos. \frac{\mu z}{\sqrt{2}} + i (A^1 - C^1) \sin. \frac{\mu z}{\sqrt{2}} \right]$$

$$+ e^{-\frac{\mu z}{\sqrt{2}}} \left[(B^1 + D^1) \cos. \frac{\mu z}{\sqrt{2}} - i (B^1 - D^1) \sin. \frac{\mu z}{\sqrt{2}} \right]$$

or, using new arbitrary constants

$$u = e^{\frac{\mu z}{\sqrt{2}}} \left[A \cos. \frac{\mu z}{\sqrt{2}} + B \sin. \frac{\mu z}{\sqrt{2}} \right] + e^{-\frac{\mu z}{\sqrt{2}}} \left[C \cos. \frac{\mu z}{\sqrt{2}} + D \sin. \frac{\mu z}{\sqrt{2}} \right]$$

The complete solution of Equation (10) is therefore

$$u = \frac{p R^2}{E_0 t} + e^{\frac{\mu z}{\sqrt{2}}} \left[A \cos. \frac{\mu z}{\sqrt{2}} + B \sin. \frac{\mu z}{\sqrt{2}} \right]$$

$$+ e^{-\frac{\mu z}{\sqrt{2}}} \left[c \cos. \frac{\mu z}{\sqrt{2}} + D \sin. \frac{\mu z}{\sqrt{2}} \right] \quad \ldots\ldots\ldots\ldots (16)$$

From this Equation (16), if $p = w\ (z + h)$, there is obtained

$$\left.\begin{aligned}
\frac{d\,u}{d\,z} &= w\,\frac{R^2}{E_0\,t} \\
&+ \frac{\mu}{\sqrt{2}}\,e^{\frac{\mu z}{\sqrt{2}}}\left[(A + B)\cos.\frac{\mu z}{\sqrt{2}} - (A - B)\sin.\frac{\mu z}{\sqrt{2}}\right] \\
&- \frac{\mu}{\sqrt{2}}\,e^{-\frac{\mu z}{\sqrt{2}}}\left[(C - D)\cos.\frac{\mu z}{\sqrt{2}} + (C + D)\sin.\frac{\mu z}{\sqrt{2}}\right] \\
\frac{d^2 u}{d\,z^2} &= \mu^2\,e^{\frac{\mu z}{\sqrt{2}}}\left[B\cos.\frac{\mu z}{\sqrt{2}} - A\sin.\frac{\mu z}{\sqrt{2}}\right] \\
&- \mu^2\,e^{-\frac{\mu z}{\sqrt{2}}}\left[D\cos.\frac{\mu z}{\sqrt{2}} - C\sin.\frac{\mu z}{\sqrt{2}}\right] \\
\frac{d^3 u}{d\,z^3} &= -\frac{\mu^3}{\sqrt{2}}\,e^{\frac{\mu z}{\sqrt{2}}}\left[(A - B)\cos.\frac{\mu z}{\sqrt{2}} + (A + B)\sin.\frac{\mu z}{\sqrt{2}}\right] \\
&+ \frac{\mu^3}{\sqrt{2}}\,e^{-\frac{\mu z}{\sqrt{2}}}\left[(C + D)\cos.\frac{\mu z}{\sqrt{2}} - (C - D)\sin.\frac{\mu z}{\sqrt{2}}\right] \\
\frac{d^4 u}{d\,z^4} &= -\mu^4\,e^{\frac{\mu z}{\sqrt{2}}}\left[A\cos.\frac{\mu z}{\sqrt{2}} + B\sin.\frac{\mu z}{\sqrt{2}}\right] \\
&- \mu^4\,e^{-\frac{\mu z}{\sqrt{2}}}\left[C\cos.\frac{\mu z}{\sqrt{2}} + D\sin.\frac{\mu z}{\sqrt{2}}\right]
\end{aligned}\right\}\quad(17)$$

Multiplying both sides of Equation (16) by μ^4 and adding to Equation (17)

$$\frac{d^4 u}{d\,z^4} + \mu^4\,u = \mu^4\,\frac{p\,R^2}{E_0\,t} = \frac{p}{C_1}\ldots\ldots\ldots\ldots\ldots(18)$$

which is Equation (10), thus verifying Equations (16) and (17).

The arbitrary constants A, B, C and D are determined by the end conditions at the crest and at the base of the dam.

Dam Free to Slide on Base.

As an example, suppose that the base is free to slide on the foundations. Then at the crest $M = F = 0$; that is, by Equations (3) and (4)

$$\frac{d^2 u}{d\,z^2} = \frac{d^3 u}{d\,z^3} = 0$$

and also at the base $M = F = 0$.

From Equations (2), (3) and (17), using the suffix 0 for the crest and suffix 1 for the base, there is found

$$\left(\frac{d^2 u}{d z^2}\right)_0 = \left(\frac{d^3 u}{d z^3}\right)_0 = \left(\frac{d^2 u}{d z^2}\right)_1 = \left(\frac{d^3 u}{d z^3}\right)_1 = 0$$

Now $z = 0$ at the crest and $z = d$ at the base. Hence, putting $z = 0$ in the second and third of Equations (17) and equating to zero,

$$B - D = 0$$
$$-(A - B) + (C + D) = 0$$

and, using the conditions at the base, putting $z = d$ in the same pair of Equations (17)

$$B\, e^{\frac{\mu d}{\sqrt{2}}} \cos. \frac{\mu d}{\sqrt{2}} - A\, e^{\frac{\mu d}{\sqrt{2}}} \sin. \frac{\mu d}{\sqrt{2}} - D\, e^{-\frac{\mu d}{\sqrt{2}}} \cos. \frac{\mu d}{\sqrt{2}}$$
$$+ \; C\, e^{-\frac{\mu d}{\sqrt{2}}} \sin. \frac{\mu d}{\sqrt{2}} = 0$$

$$A\, e^{\frac{\mu d}{\sqrt{2}}} \left(\cos. \frac{\mu d}{\sqrt{2}} + \sin. \frac{\mu d}{\sqrt{2}}\right) - B\, e^{\frac{\mu d}{\sqrt{2}}} \left(\cos. \frac{\mu d}{\sqrt{2}} - \sin. \frac{\mu d}{\sqrt{2}}\right)$$
$$+ \; C e^{-\frac{\mu d}{\sqrt{2}}} \left(\cos. \frac{\mu d}{\sqrt{2}} - \sin. \frac{\mu d}{\sqrt{2}}\right) + D e^{-\frac{\mu d}{\sqrt{2}}} \left(\cos. \frac{\mu d}{\sqrt{2}} + \sin. \frac{\mu d}{\sqrt{2}}\right) = 0$$

Hence

$$A = B = C = D = 0$$

and the solution becomes simply

$$u = \frac{w\, R^2}{E_0\, t} \times z \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (19)$$

hence, by means of Equation (4),

$$T = \frac{E_0\, t}{R} \times u = w\, R\, z = p\, R \ldots\ldots\ldots\ldots\ldots (20)$$

which is the ordinary cylinder formula.

The condition which must be satisfied for this formula to be applicable is, therefore, that the dam is free to move, or slide, on its foundations.

Dam with Base Encastrée.

As another example, suppose that the base is fixed and encastrée, then at the base the conditions to be satisfied are

$$u = \frac{d\, u}{d\, z} = 0$$

In this case it will simplify the work to take the origin at the base and the axis of Z vertical upward.

The fundamental Equation (10) is then unaltered in form, but the pressure is given by

$$p = w\,(d - z) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (21)$$

The solution, Equation (16), remains the same in form but with p as given in Equation (21) and hence $\dfrac{d\,p}{d\,z} = -\,w$, so that in the first of Equations (17) the sign of w must be altered from $+$ to $-$. In order to determine the constants, apply the conditions that

when $z = 0$, $\qquad u = \dfrac{d\,u}{d\,z} = 0$

when $z = d$, $\qquad M = F = 0$

Therefore $\qquad \dfrac{d^2\,u}{d\,z^2} = \dfrac{d^3\,u}{d\,z^3} = 0$

Hence, from Equation (16) and the first of Equations (17), putting $z = 0$

$$\left.\begin{aligned} &\frac{w\,R^2\,d}{E_0\,t} + A + C = 0 \\ -&\frac{w\,r^2}{E_0\,t} + \frac{\mu}{\sqrt{2}}\left[(A + B) - (C - D)\right] = 0 \end{aligned}\right\} \ldots\ldots\ldots (22)$$

For the crest of the dam, putting $z = d$ in the second and third of Equations (17) and equating to zero as before

$$\left.\begin{aligned} &-A\,e^{\frac{\mu d}{\sqrt{2}}}\sin.\frac{\mu\,d}{\sqrt{2}} + B\,e^{\frac{\mu d}{\sqrt{2}}}\cos.\frac{\mu\,d}{\sqrt{2}} + C\,e^{-\frac{\mu d}{\sqrt{2}}}\sin.\frac{\mu\,d}{\sqrt{2}} \\ &\qquad - D\,e^{-\frac{\mu d}{\sqrt{2}}}\cos.\frac{\mu\,d}{\sqrt{2}} = 0 \\ &A\,e^{\frac{\mu d}{\sqrt{2}}}\left(\cos.\frac{\mu\,d}{\sqrt{2}} + \sin.\frac{\mu\,d}{\sqrt{2}}\right) - B\,e^{\frac{\mu d}{\sqrt{2}}}\left(\cos.\frac{\mu\,d}{\sqrt{2}} - \sin.\frac{\mu\,d}{\sqrt{2}}\right) \\ &\qquad + C\,e^{-\frac{\mu d}{\sqrt{2}}}\left(\cos.\frac{\mu\,d}{\sqrt{2}} - \sin.\frac{\mu\,d}{\sqrt{2}}\right) \\ &\qquad + D\,e^{-\frac{\mu d}{\sqrt{2}}}\left(\cos.\frac{\mu\,d}{\sqrt{2}} + \sin.\frac{\mu\,d}{\sqrt{2}}\right) = 0 \end{aligned}\right\} (23)$$

Since

$$\mu^4 = 12\,\frac{E_0}{E_1} \times \frac{1}{t^2\,R^2}$$

$$\frac{\mu}{\sqrt{2}} = \frac{1}{\sqrt{t\,R}}\left(3\,\frac{E_0}{E_1}\right)^{\frac{1}{4}}$$

Suppose, for simplicity, $E_0 = E_1$; then

$$\frac{\mu}{\sqrt{2}} = \frac{3\frac{1}{4}}{\sqrt{t\,R}} = \frac{1.3}{\sqrt{t\,R}} \text{ nearly.}$$

In most ordinary cases $e^{-2\frac{\mu d}{\sqrt{2}}}$, can be neglected. Dividing the two Equations (23) by $e^{\frac{\mu d}{\sqrt{2}}}$ and neglecting $e^{-2\frac{\mu d}{\sqrt{2}}}$, there is found

$$-A \sin.\frac{\mu d}{\sqrt{2}} + B \cos.\frac{\mu d}{\sqrt{2}} = 0$$

$$A\left(\cos.\frac{\mu d}{\sqrt{2}} + \sin.\frac{\mu d}{\sqrt{2}}\right) - B\left(\cos.\frac{\mu d}{\sqrt{2}} - \sin.\frac{\mu d}{\sqrt{2}}\right) = 0$$

So that

$$A = B = 0$$

Hence, from Equation (22)

$$C = -\frac{w\,R^2\,d}{E_0\,t}$$

$$D = \frac{w\,R^2}{E_0\,t}\left(\frac{\sqrt{2}}{\mu} - d\right)$$

The solution of Equation (16) then becomes, using Equation (21),

$$u = \frac{w\,R^2}{E_0 t}(d - z) - \frac{w\,R^2}{E_0 t}e^{-\frac{\mu z}{\sqrt{2}}}\left[d \cos.\frac{\mu z}{\sqrt{2}} + \left(d - \frac{\sqrt{2}}{\mu}\right)\sin.\frac{\mu z}{\sqrt{2}}\right]$$

In order to fix the meaning of these equations, consider a cylindrical dam 18 ft. in diameter, 20 ft. deep, and 9 in. thick. In this case, taking $E_0 = E_1$,

$$\frac{\mu}{\sqrt{2}} = \frac{1.3}{\sqrt{\frac{3}{4} \times 9}} = \frac{1.3}{2.6} = \frac{1}{2}$$

very nearly and

$$u = \frac{w\,R^2}{E_0\,t}\left[(d - z) - e^{-\frac{1}{2}z}\left\{d \cos.\frac{1}{2}z + (d - z)\sin.\frac{1}{2}z\right\}\right] \quad (24)$$

the exponential term becomes very small when z is greater than 4 ft. above the base, and this portion of the expression may therefore be neglected, thus reducing to

$$u = \frac{w\,R^2}{E_0\,t}(d - z) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (25)$$

from which, using Equations (4) and (21)

$$T = p\,R.$$

So that the ordinary cylinder formula becomes applicable within quite a moderate distance of the base, and similarly in any case when $\frac{\mu z}{\sqrt{2}}$ becomes large.

The bending moment at the base is given by Equation (3) and the second of Equations (17). Thus, observing that $z = 0$ and using the values of constants just determined,

$$
\begin{aligned}
M &= C_1 \frac{d^2 u}{d z^2} \\
&= \frac{1}{12} E_1 t^3 \times \mu^2 (B - D) \\
&= -\frac{1}{12} E_1 t^3 \times \mu^2 D \\
&= -\frac{1}{12} E_1 t^3 \times \mu^2 \times \frac{w R^2}{E_0 t} \left(\frac{\sqrt{2}}{\mu} - d \right) \\
&= -\frac{w}{\mu^2} \left(\frac{\sqrt{2}}{\mu} - d \right) \\
&= \frac{w}{\mu^2} \left(d - \frac{\sqrt{2}}{\mu} \right) \qquad \text{(26)}
\end{aligned}
$$

In the case considered above, $\mu^2 = \frac{1}{2}$ and $M = 2\, w\, (d - 2) = 2 \times 62.5 \times 18 = 2250$ ft. lb. per foot width.

If instead of a dam in which the water pressure is applied outside, the case of a tank is considered, the sign of p is changed. This case may be dealt with by changing the sign of w, which will then change the arch thrust into a tension and change the sign of the bending moment, and also of course change the sign of u.

Case 2.—Arched Dams of Wedge Shaped Section.

In treating the case of arched dams with wedge shaped sections in which the thickness is finite at the crest and increases uniformly with the depth, take the origin at the intersection of the upstream and downstream faces and measure z vertically downward. Let

$$t = c\, z \qquad \text{(27)}$$

If l_1 is the distance of the water surface below the origin,

$$p = w\, (z - l_1) \qquad \text{(28)}$$

where w is the pressure in pounds per square foot per foot in depth, or the weight of 1 cu. ft. of water, 62.5 lb. Then

$$C_1 = E_1 I = \frac{1}{12} E_1 t^3 = \frac{1}{12} E_1 c^3 z^3 \ldots\ldots\ldots\ldots (29)$$

Substituting in Equation (7)

$$\frac{1}{12} E_1 c^3 \frac{d^2}{d z^2} \left(z^3 \frac{d^2 u}{d z^2} \right) + \frac{E_0}{R^2} \times c \times z u = p$$

or dividing by $\frac{1}{12} E_1 c^3$

$$\frac{d^2}{d z^2} \left(z^3 \frac{d^2 u}{d z^2} \right) + 12 \, . \frac{E_0}{E_1} \times \frac{1}{c^2 R^2} \times z u = \frac{12 p}{E_1 c^3} \ldots\ldots (30)$$

Let

$$z = a x \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (31)$$

Substituting in Equation (30) and multiplying by a

$$\frac{d^2}{d x^2} \left(x^3 \frac{d^2 u}{d x^2} \right) + 12 \frac{E_0}{E_1} \times \frac{a^2}{c^2 R^2} \times x u = \frac{12 p a}{E_1 c^3} \ldots\ldots (32)$$

If $l' = a l_1$, the right hand side of Equation (32) becomes, using Equation (28)

$$\frac{12 w a^2 (x - l')}{E_1 c^3}$$

Now, suppose that a is chosen so that

$$12 \frac{E_0}{E_1} \times \frac{a^2}{c^2 R^2} = 1 \ldots\ldots\ldots\ldots\ldots\ldots (33)$$

Then Equation (32) becomes

$$\frac{d^2}{d x^2} \left(x^3 \frac{d^2 u}{d x^2} \right) + x u = \frac{w R^2}{E_0 c} (x - l') \ldots\ldots\ldots\ldots (34)$$

which is the fundamental equation on which the solution is based.

A particular integral of Equation (34) is of the form

$$u = A + \frac{B}{x} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (35)$$

for this gives

$$u x = A x + B$$

and

$$\frac{d u}{d x} = - \frac{B}{x^2}$$

$$\frac{d^2 u}{d x^2} = + \frac{2 B}{x^3}$$

so that

$$x^3 \frac{d\ u}{d\ x^2} = 2\ B$$

$$\frac{d}{d\ x}\left(x^3 \frac{d^2\ u}{d\ x^2}\right) = 0$$

$$\frac{d^2}{d\ x^2}\left(x^3 \frac{d^2\ u}{d\ x^2}\right) = 0$$

Substituting in Equation (34)

$$A\ x + B = \frac{w\ R^2}{E_0\ c}\,(x - l')$$

Hence

$$A = \frac{w\ R^2}{E_0\ c}$$

$$B = -\frac{w\ R^2}{E_0\ c}\ l'$$

so that a particular integral of Equation (34) is

$$u = \frac{w\ R^2}{E_0\ c}\left(1 - \frac{l'}{x}\right) \qquad \text{(36)}$$

A general solution (the complementary function) of the Equation

$$\frac{d^2}{d\ x^2}\left(x^3 \frac{d^2\ u}{d\ x^2}\right) + x\ u = 0 \qquad \text{(37)}$$

may be stated, as follows:

Solution in Series—Michell's Functions.

The four solutions of Equation (37) in series form are

$$\left.\begin{aligned}
u_1 &= 1 - \frac{3\ x^2}{(|\underline{3})^2} + \frac{5\ x^4}{(|\underline{5})^2} - \ldots\ldots \\
u_2 &= 4\left[\frac{1\ .\ x}{(|\underline{2})^2} - \frac{2\ .\ x^3}{(|\underline{4})^2} + \frac{3\ .\ x^5}{(|\underline{6})^2} - \ldots\ldots\right] \\
u_3 &= u_1\,(\log.\ x + 2) + \left[1 - \frac{x^2}{(|\underline{3})^2} + \frac{x^4}{(|\underline{5})^2} - \ldots\ldots\right] \\
&\quad - 2\left[1 - \frac{3\ x^2}{(|\underline{3})^2}\,S_3 + \frac{5\ x^4}{(|\underline{5})^2}\,S_5 - \ldots\ldots\right] \\
u_4 &= -\frac{1}{2}\,u_2 \log.\ x + \frac{1}{x} - \frac{x}{(|\underline{2})^2} + \frac{x^3}{(|\underline{4})^2} - \ldots\ldots \\
&\quad + 4\left[\frac{1\ .\ x}{(|\underline{2})^2}\,S_2 - \frac{2\ .\ x^3}{(|\underline{4})^2}\,S_4 + \ldots\ldots\right]
\end{aligned}\right\} \text{(38)}$$

where
$$S_n = \frac{1}{1} + \frac{1}{2} + \ldots\ldots + \frac{1}{n}$$
and
$$\underline{|n} = 1 \times 2 \times 3 \times \ldots\, n$$
This can be verified by differentiation of each series in Equation (38). These will be called Michell's functions.

Solution in Complex Bessel Functions.

A solution of Equation (37) may also be obtained as follows:

Let
$$\left.\begin{aligned} \zeta^4 + (4\,x)^2 &= 0 \\ \zeta &= \pm\sqrt{2\,x}\,(1 \pm i) \end{aligned}\right\} \qquad (39)$$
Then a solution of Equation (37) is
$$u = \frac{1}{\zeta} J_1(\zeta) \qquad (40)$$
where J_1 is a Bessel's function of the first order, defined by Bessel's Equation
$$\frac{d^2 J_n}{d\,\zeta^2} + \frac{1}{\zeta} \cdot \frac{d\,J_n}{d\,\zeta} + \left(1 - \frac{n^2}{\zeta^2}\right) J_n = 0 \qquad (41)$$
with $n = 1$. This can also be verified by differentiating Equation (40) and using Equations (39) and (41). The four values of ζ give rise to four different solutions of Equation (37).

Connection Between Michell's and Bessel's Functions.

By comparison of the known series for Bessel's functions with the series given above for Michell's functions,
$$\left.\begin{aligned} u_1 &= \frac{1}{\zeta} J_1(\zeta) + \frac{1}{\zeta'} J_1(\zeta') \\ u_2 &= 2\,i\left[\frac{1}{\zeta}\,(J_1(\zeta) - \frac{1}{\zeta'} J_1(\zeta')\right] \\ u_3 &= -2\,(\log.\,2 - 1)\,u_1 - \frac{\pi}{4} u_2 + 2\left[\frac{1}{\zeta} Y_1(\zeta) + \frac{1}{\zeta'} Y_1(\zeta')\right] \\ u_4 &= -\frac{\pi}{2} u_1 + (\log.\,2)\,u_2 - 2\,i\left[\frac{1}{\zeta} Y_1(\zeta) - \frac{1}{\zeta'} Y_1(\zeta')\right] \end{aligned}\right\} \quad (42)$$
where
$$\zeta = \sqrt{2x}\,(1 + i)$$
$$\zeta' = \sqrt{2x}\,(1 - i)$$

and Y_1* is the usual second solution of Bessel's Equation for $n = 1$. Equations (38) and (42) are of course convertible one from the other.

The complete solution of Equation (34) is

$$u = \frac{w\,R^2}{E_0\,c}\left(1 - \frac{l'}{x}\right) + A\,u_1 + B\,u_2 + C\,u_3 + D\,u_4 \ldots\ldots (43)$$

where A, B, C, D are the four arbitrary constants which are to be determined by the boundary conditions at the crest and at the base, exactly as in Case 1.

Tables of Michell's Functions.

In order to facilitate calculation, tables of Michell's functions have been prepared, giving u_1, u_2, u_3, u_4 and their first three derivatives for all integral values of x from 1 to 30. Attention is drawn to the fact that the values of x are not actual heights, but are merely numbers connected with the height by the relation $z = a\,x$, where a is given by Equation (33), namely,

$$12\,\frac{E_0}{E_1} \times \frac{a^2}{c^2\,R^2} = 1$$

For example, if

$$E_1 = E_0$$

$$c = \frac{1}{6}$$

$$R = 150$$

Then

$$a^2 = \left(\frac{1}{6} \times 150\right)^2 \times \frac{1}{12}$$

$$a = \frac{25}{2\sqrt{3}} = 7.2 = \frac{36}{5} \text{ about.}$$

and the values of x are about $\frac{5}{36}$ of the actual vertical height, so that for a dam of these proportions 180 ft. high the value of x is 25.

The tables have been calculated direct from the Equation (42). For values of x above 10, this work is troublesome on account of the large number of terms which must be included—and for values of x above 20 the tables cannot be relied upon for more than about four

* There is an error in Gray and Matthews expression for Y_n. The sign of the last term $\left(\Sigma^n \frac{1}{2\,S}\right)$ should be +, not − as given. The correct expression is given in Jahnke and Emde's Tables.

TABLE 1.—MICHELL'S FUNCTIONS.

x	u_1	$\frac{d\,u_1}{d\,x}$	$\frac{d^2\,u_1}{d\,x^2}$	$\frac{d^3\,u_1}{d\,x^3}$
0.0	+ 1.000 000 00	0.000 000 00	− 0.166 666 67	0.000 000 00
0.5	+ 0.979 188 37	− 0.083 159 77	− 0.165 625 52	+ 0.004 162 54
1.0	+ 0.917 013 61	− 0.165 279 43	− 0.162 508 27	+ 0.008 300 28
1.5	+ 0.814 254 68	− 0.245 325 05	− 0.157 333 48	+ 0.012 388 56
2	+ 0.672 204 62	− 0.322 275 06	− 0.150 132 03	+ 0.016 402 85
3	+ 0.277 924 57	− 0.462 900 59	− 0.129 833 52	+ 0.024 112 71
4	− 0.245 568 72	− 0.579 461 96	− 0.102 100 76	+ 0.031 240 37
5	− 0.870 598 64	− 0.664 846 63	− 0.067 607 44	+ 0.037 604 44
6	− 1.562 742 75	− 0.712 704 78	− 0.027 203 43	+ 0.043 034 32
7	− 2.281 681 64	− 0.717 619 62	+ 0.018 097 18	+ 0.047 372 63
8	− 2.982 211 69	− 0.675 261 69	+ 0.067 130 53	+ 0.050 477 59
9	− 3.615 407 80	− 0.582 546 36	+ 0.118 599 70	+ 0.052 225 29
10	− 4.129 918 35	− 0.437 722 61	+ 0.171 093 76	+ 0.052 511 72
11	− 4.473 374 86	− 0.240 516 84	+ 0.223 108 43	+ 0.051 254 73
12	− 4.593 893 87	+ 0.007 810 04	+ 0.273 068 90	+ 0.048 395 59
13	− 4.441 650 25	+ 0.304 396 08	+ 0.319 354 00	+ 0.043 900 50
14	− 3.970 495 65	+ 0.644 745 53	+ 0.360 321 76	+ 0.037 761 84
15	− 3.139 599 09	+ 1.022 721 39	+ 0.394 335 93	+ 0.029 999 04
16	− 1.915 079 57	+ 1.430 564 76	+ 0.419 793 88	+ 0.020 659 31
17	− 0.271 608 29	+ 1.858 942 21	+ 0.435 153 85	+ 0.009 818 12
18	+ 1.806 054 11	+ 2.297 021 19	+ 0.438 963 88	− 0.002 420 86
19	+ 4.321 605 72	+ 2.732 573 71	+ 0.429 889 85	− 0.015 925 78
20	+ 7.265 874 30	+ 3.152 108 15	+ 0.406 743 22	− 0.030 537 14
21	+ 10.615 627 17	+ 3.541 028 62	+ 0.368 508 53	− 0.046 068 67
22	+ 14.332 564 33	+ 3.883 821 38	+ 0.314 369 58	− 0.062 308 22
23	+ 18.362 491 81	+ 4.164 266 66	+ 0.243 734 64	− 0.079 019 39
24	+ 22.634 750 91	+ 4.365 674 43	+ 0.156 259 75	− 0.095 943 11
25	+ 27.061 858 63	+ 4.471 144 92	+ 0.051 870 58	− 0.112 799 69
26	+ 31.539 446 51	+ 4.463 845 83	− 0.069 218 03	− 0.129 290 98
27	+ 35.946 464 68	+ 4.327 312 54	− 0.206 485 17	− 0.145 103 20
28	+ 40.145 720 43	+ 4.045 759 93	− 0.359 089 25	− 0.159 909 51
29	+ 43.984 701 53	+ 3.604 409 37	− 0.525 856 73	− 0.173 373 28
30	+ 47.296 773 74	+ 2.989 826 06	− 0.705 273 93	− 0.185 151 34

TABLE 1.—MICHELL'S FUNCTIONS (*Continued*).

x	u_2	$\frac{d\,u_2}{d\,x}$	$\frac{d^2\,u_2}{d\,x^2}$	$\frac{d^3\,u_2}{d\,x^3}$
0	0.000 000 00	+ 1.000 000 00	0.000 000 00	— 0.083 333 33
0.5	+ 0.498 264 61	+ 0.989 590 56	— 0.041 608 81	— 0.082 986 24
1.0	+ 0.986 134 25	+ 0.958 449 00	— 0.082 870 78	— 0.081 946 51
1.5	+ 1.453 300 61	+ 0.906 835 16	— 0.123 440 64	— 0.080 218 78
2	+ 1.889 628 37	+ 0.835 180 77	— 0.162 976 19	— 0.077 810 79
3	+ 2 630 603 51	+ 0.634 324 87	— 0.237 600 21	— 0.071 000 18
4	+ 3.134 653 96	+ 0.362 681 67	— 0.304 125 19	— 0.061 637 08
5	+ 3.335 460 91	+ 0.029 600 16	— 0.360 079 53	— 0.049 890 94
6	+ 3.177 260 17	— 0.353 191 40	— 0.403 183 80	— 0.035 976 37
7	+ 2.617 117 81	— 0.771 799 91	— 0.431 394 77	— 0.020 150 68
8	+ 1.626 970 39	— 1.210 424 47	— 0.442 946 81	— 0.002 711 11
9	+ 0.195 386 64	— 1.651 653 30	— 0.436 389 88	+ 0.016 008 77
10	— 1.670 984 70	— 2.076 797 10	— 0.410 624 26	+ 0.035 642 75
11	— 3.946 317 91	— 2.466 254 73	— 0.364 930 94	+ 0.055 796 29
12	— 6 584 893 70	— 2.799 907 55	— 0.298 997 71	+ 0.076 051 10
13	— 9.520 788 54	— 3.057 537 21	— 0.212 940 47	+ 0.095 970 28
14	— 12.667 991 09	— 3.219 262 07	— 0.107 319 11	+ 0.115 103 45
15	— 15.920 965 31	— 3.265 987 15	+ 0.016 851 73	+ 0.132 992 51
16	— 19.155 663 04	— 3.179 861 76	+ 0.158 097 74	+ 0.149 177 26
17	— 22.230 999 12	— 2.944 739 20	+ 0.314 485 97	+ 0.163 201 55
18	— 24.990 784 34	— 2.546 632 30	+ 0.483 631 82	+ 0.174 619 26
19	— 27.266 108 15	— 1.974 159 47	+ 0.662 712 11	+ 1.183 000 57
20	— 28.878 160 46	— 1.218 973 04	+ 0.818 484 67	+ 0.187 938 11
21	— 29.641 471 50	— 0.276 167 16	+ 1.037 313 72	+ 0.189 053 12
22	— 29.367 546 82	+ 0.855 344 59	+ 1.225 201 64	+ 0.186 001 69
23	— 27,868 859 01	+ 2.172 484 82	+ 1.407 826 66	+ 0.178 480 55
24	— 24.963 161 96	+ 3.667 711 54	+ 1.580 586 63	+ 0 166 232 86
25	— 20.478 106 07	+ 5.328 760 15	+ 1.738 647 89	+ 0.149 053 82
26	— 14.256 042 31	+ 7.138 439 21	+ 1.877 000 43	+ 0.126 795 76
27	— 6.159 046 69	+ 9.074 483 33	+ 1.990 517 00	+ 0,099 373 07
28	+ 3 915 959 04	+ 11.109 468 21	+ 2 074 017 81	+ 0.066 766 59
29	+ 16.082 060 19	+ 13.210 791 30	+ 2.122 338 41	+ 0.029 027 64
30	+ 30.357 139 10	+ 15.340 724 50	+ 2.130 402 95	— 0.013 718 64

TABLE 1.—MICHELL'S FUNCTIONS (*Continued*).

x	u_3	$\frac{d\,u_3}{d\,x}$	$\frac{d^2\,u_3}{d\,x^2}$	$\frac{d^3\,u_3}{d\,x^3}$
0	— ∞	+ ∞	— ∞	+ ∞
0.5	+ 0.349 004 77	+ 2.126 719 09	— 4.144 436 91	+ 15.658 444 26
1.0	+ 1.110 290 19	+ 1.135 953 82	— 1.035 186 21	+ 1.822 719 02
1.5	+ 1.576 001 25	+ 0.765 643 46	— 0.552 622 35	+ 0.470 733 17
2	+ 1.897 286 64	+ 0.531 027 16	— 0.411 210 41	+ 0.157 286 94
3	+ 2.239 378 55	+ 0.163 228 26	— 0.346 617 64	+ 0.015 074 63
4	+ 2.230 395 63	— 0.181 058 30	— 0.345 095 73	— 0.004 824 19
5	+ 1.876 011 40	— 0.528 346 17	— 0.348 718 95	— 0.000 476 59
6	+ 1.173 657 67	— 0.875 537 05	— 0.343 705 73	+ 0.011 201 12
7	+ 0.128 715 35	— 1.211 303 06	— 0.325 409 68	+ 0.025 675 90
8	— 1.240 371 91	— 1.521 304 00	— 0.291 993 12	+ 0.041 256 34
9	— 2.900 136 83	— 1.790 029 50	— 0.242 819 28	+ 0.057 079 05
10	— 4.861 410 45	— 2.001 704 52	— 0.177 949 01	+ 0.072 563 34
11	— 6.879 371 71	— 2.140 883 82	— 0.097 962 53	+ 0.087 238 49
12	— 9.054 118 78	— 2.192 927 27	— 0.003 882 53	+ 0.100 682 94
13	— 11.231 692 52	— 2.144 423 19	+ 0.102 861 84	+ 0.112 503 49
14	— 13.305 497 46	— 1.983 582 03	+ 0.220 459 24	+ 0.122 329 02
15	— 15.158 119 16	— 1.700 607 20	+ 0.346 738 07	+ 0.129 810 42
16	— 16.663 486 32	— 1.288 044 38	+ 0.479 190 22	+ 0.134 623 04
17	— 17.689 383 31	— 0.741 105 97	+ 0.614 995 85	+ 0.136 470 94
18	— 18.100 261 75	— 0.057 965 33	+ 0.751 055 62	+ 0.135 090 38
19	— 17.760 342 35	+ 0.759 977 28	+ 0.884 024 64	+ 0.130 253 90
20	— 16.536 949 62	+ 1.707 871 62	+ 1.010 351 55	+ 0.121 779 09
21	— 14.304 071 56	+ 2.777 229 12	+ 1.126 322 11	+ 0.109 522 89
22	— 10.946 049 13	+ 3.955 787 69	+ 1.228 106 47	+ 0.093 395 61
23	— 6.361 430 31	+ 5.227 415 57	+ 1.311 809 78	+ 0.073 358 90
24	— 0.466 832 30	+ 6.572 076 93	+ 1.373 526 39	+ 0.049 430 10
25	+ 6.799 134 31	+ 7.965 851 35	+ 1.409 397 20	+ 0.021 684 77
26	+ 15.472 035 19	+ 9.381 002 59	+ 1.415 668 81	— 0.009 740 74
27	+ 25.557 832 98	+ 10.786 124 32	+ 1.388 754 59	— 0.044 648 47
28	+ 37.029 338 23	+ 12.146 327 15	+ 1.325 297 95	— 0.082 776 97
29	+ 49.822 839 52	+ 13.423 513 56	+ 1.222 235 05	— 0.123 801 40
30	+ 63.835 054 69	+ 14.576 687 67	+ 1.076 858 96	— 0.167 333 26

TABLE 1.—MICHELL'S FUNCTIONS (*Continued*).

x	u_4	$\frac{d\,u_4}{d\,x}$	$\frac{d^2\,u_4}{d\,x^2}$	$\frac{d^3\,u_4}{d\,x^3}$
0	$+\infty$	$-\infty$	$+\infty$	$-\infty$
0.5	+ 2.794 287 19	— 2.925 680 85	+ 14.921 467 33	— 94.114 880 95
1.0	+ 2 222 855 68	— 0.324 390 60	+ 1.372 518 26	— 5.584 067 47
1.5	+ 2.155 654 02	— 0.044 932 10	+ 0.094 914 87	— 1.027 358 73
2	+ 2.129 261 86	— 0.083 876 56	— 0.192 562 13	— 0.298 945 42
3	+ 1.917 207 03	— 0.360 304 18	— 0.320 973 68	— 0.042 036 12
4	+ 1.392 154 36	— 0.691 902 35	— 0.334 432 07	+ 0.006 357 67
5	+ 0.535 173 75	— 1.018 939 64	— 0.315 865 84	+ 0.029 250 11
6	— 0.636 048 21	— 1.317 101 62	— 0.277 489 98	+ 0.047 099 60
7	— 2.083 355 94	— 1.568 297 44	— 0.222 211 95	+ 0.063 242 81
8	— 3.751 582 58	— 1.756 353 31	— 0.151 418 05	+ 0.078 128 62
9	— 5.570 043 42	— 1.866 399 35	— 0.066 431 09	+ 0.091 581 37
10	— 7.453 883 62	— 1.885 010 29	+ 0.031 159 51	+ 0,103 278 11
11	— 9.305 673 20	— 1.800 518 82	+ 0.139 423 62	+ 0.112 870 86
12	— 11.017 337 84	— 1.603 359 64	+ 0.256 087 58	+ 0.120 023 73
13	— 12.472 430 03	— 1.286 405 96	+ 0.378 554 21	+ 0.124 427 11
14	— 13.548 725 43	— 0.845 277 40	+ 0.503 933 06	+ 0.125 805 31
15	— 14.121 105 43	— 0.278 625 73	+ 0.629 076 96	+ 0.123 921 27
16	— 14.064 708 02	+ 0.411 679 21	+ 0.750 623 21	+ 0.118 581 57
17	— 13.258 279 78	+ 1.220 255 18	+ 0.865 038 76	+ 0.109 639 66
18	— 11.587 713 13	+ 2.138 162 36	+ 0.968 669 32	+ 0.097 000 02
19	— 8.949 685 37	+ 3.152 758 15	+ 1.057 791 69	+ 0.080 620 83
20	— 5.255 386 92	+ 4.247 663 57	+ 1.128 668 90	+ 0.060 516 98
21	— 0.434 246 91	+ 5.402 781 86	+ 1.177 608 08	+ 0.036 762 19
22	+ 5.562 370 74	+ 6.594 369 44	+ 1.201 020 39	+ 0.009 490 77
23	+ 12.757 600 27	+ 7.795 169 95	+ 1.195 482 01	— 0.021 101 15
24	+ 21.145 624 79	+ 8.974 613 93	+ 1.157 796 86	— 0.054 754 82
25	+ 30.688 529 39	+ 10.099 074 80	+ 1.085 058 24	— 0.091 149 31
26	+ 41.313 351 99	+ 11.132 189 61	+ 0.974 711 76	— 0.129 901 64
27	+ 52.909 577 44	+ 12.035 243 78	+ 0.824 616 45	— 0.170 568 24
28	+ 65.343 611 83	+ 12.767 789 77	+ 0.633 097 76	— 0.212 646 48
29	+ 78.373 901 86	+ 13.287 260 53	+ 0.399 037 69	— 0.255 579 30
30	+ 91.816 273 29	+ 13.551 308 17	+ 0.121 864 48	— 0.298 753 96

decimal places. In case it should be desired to use the functions for higher values than those given in the tables, it has been thought advisable to give the semi-converging expressions for Michell's functions, as follows. Let*

$$P_n = 1 - \frac{(4n^2 - 1^2)(4n^2 - 3^2)}{\lfloor 2 \, (8\zeta)^2} + \frac{(4n^2 - 1^2)(4n^2 - 3^2)(4n^2 - 5^2)(4n^2 - 7^2)}{\lfloor 4 \, (8\zeta)^4} - \ldots$$

$$Q_n = \frac{4n^2 - 1^2}{8\zeta} - \frac{(4n^2 - 1^2)(4n^2 - 3^2)(4n^2 - 5^2)}{\lfloor 3 \, (8\zeta)^3} + \ldots$$

and putting $n = 1$, there results

$$P_1 = 1 + \frac{3 \times 5}{\lfloor 2 \, (8\zeta)^2} - \frac{3 \times 5 \times 21 \times 45}{\lfloor 4 \, (8\zeta)^4} + \ldots$$

$$Q_1 = \frac{3}{8\zeta} - \frac{3 \times 5 \times 21}{\lfloor 3 \, (8\zeta)^3} + \ldots$$

write

$$\begin{aligned} \zeta &= \sqrt{2x}\,(1 + i) \\ \zeta' &= \sqrt{2x}\,(1 - i) \\ P_1 &= A - iB \\ Q_1 &= C - iD \\ P_1^1 &= A + iB \\ Q_1^1 &= C + iD \end{aligned}$$

where

$$A = 1 + 0.009012 \times \frac{1}{x^2}$$

$$B = \quad + 0.029297 \times \frac{1}{x}$$

$$C = \frac{1}{16\sqrt{2x}}\left(3 + 0.20508 \times \frac{1}{x}\right)$$

$$D = \frac{1}{16\sqrt{2x}}\left(3 - 0.20508 \times \frac{1}{x}\right)$$

and call

$$\begin{aligned} \alpha &= \left(\sin.\sqrt{2x} - \cos.\sqrt{2x}\right)\ \cosh.\sqrt{2x} \\ \beta &= \left(\sin.\sqrt{2x} + \cos.\sqrt{2x}\right)\ \sinh.\sqrt{2x} \\ \gamma &= \left(\sin.\sqrt{2x} + \cos.\sqrt{2x}\right)\ \cosh.\sqrt{2x} \\ \delta &= \left(\sin.\sqrt{2x} - \cos.\sqrt{2x}\right)\ \sinh.\sqrt{2x} \end{aligned}$$

* Gray and Matthews "Treatise on Bessel Functions", p. 38. (McMillan and Co., London and New York).

where, as usual, the hyperbolic functions are defined by

$$\cosh.\ \theta = \frac{1}{2}\left(e^{\theta} + e^{-\theta}\right)$$

$$\sinh.\ \theta = \frac{1}{2}\left(e^{\theta} - e^{-\theta}\right)$$

also let

$$H = \sqrt{\sqrt{2} + 1} - \sqrt{\sqrt{2} - 1} = 0.910181$$

$$K = \sqrt{\sqrt{2} + 1} - \sqrt{\sqrt{2} - 1} = 2.197365$$

Then the semi-convergent expressions for Michell's functions* are from the expressions for J_n and Y_n in Gray and Matthews, by substituting $\zeta = \sqrt{2x}\,(1 + i)$ and $\zeta' = \sqrt{2x}\,(1 - i)$ in

$$J_n(\xi)\ \sqrt{\frac{2}{\pi\xi}}\left[P_n \cos.\ \left(\frac{(2n+1)\pi}{4} - \xi\right) + Q_n \sin.\ \left(\frac{(2n+1)\pi}{4} - \xi\right)\right]$$

$$Y_n(\xi) = (\log.\ 2 - \gamma) J_n(\xi) + \sqrt{\frac{\pi}{2\xi}}\left[Q_n \cos.\left(\frac{(2n+1)\pi}{4} - \xi\right)\right.$$
$$\left. - P_n \sin.\left(\frac{(2n+1)\pi}{4} - \xi\right)\right]$$

where P_n and Q_n have the values given above and γ is Euler's constant 0.577215.....while log. 2 is the Naperian logarithm of 2 or 0.693147 ...., so that $(\log.\ 2 - \gamma) = 0.115931....$

The required expressions are

$$u_1 = \frac{1}{2\sqrt{\pi}\,(2x)^{\frac{3}{4}}}\left[H\,(A\,\alpha + B\,\beta + C\,\gamma - D\,\delta)\right.$$
$$\left. + K\,(A\,\beta - B\,\alpha - c\,\delta - D\,\gamma)\right]$$

$$u_2 = \frac{1}{\sqrt{\pi}\,(2\,x)^{\frac{3}{4}}}\left[H\,(-A\,\beta + B\,\alpha + C\,\delta + D\,\gamma)\right.$$
$$\left. + K\,(A\,\alpha + B\,\beta + C\,\gamma - D\,\delta)\right]$$

$$u_3 = 2\,(1 - \gamma)\,u_1 - \frac{\pi}{4}\,u_2 + \frac{\sqrt{\pi}}{2\,(2\,x)^{\frac{3}{4}}}\left[H\,(-A\,\gamma + B\,\delta + C\,\alpha + D\,\beta)\right.$$
$$\left. + K\,(A\,\delta + B\,\gamma + C\,\beta - D\,\alpha)\right]$$

$$u_4 = -\frac{\pi}{2}\,u_1 + \gamma\,u_2 - \frac{\sqrt{\pi}}{2\,(2\,x)^{\frac{3}{4}}}\left[H\,(A\,\delta + B\,\gamma + C\,\beta - D\,\alpha)\right.$$
$$\left. + K\,(A\,\gamma - B\,\delta - C\,\alpha - D\,\beta)\right]$$

* Gray and Matthews "Bessel Functions", p. 40.

CONNECTION BETWEEN SOLUTION FOR DAMS FOR UNIFORM THICKNESS AND TRIANGULAR SECTIONS.

In order to establish the connection between the solution in the case of the wedge shaped section and the dam of constant thickness, suppose z, and therefore also x, to become indefinitely large and c indefinitely small, so that

$$t = c\,z = c\,(z_0 + z')$$

Where z' is very small, $t = c\,z_0$, approximately constant.

Then, referring to Equations (9), (10), and (33),

$$\mu^4 = \frac{E_0\,t}{C_1 R^2} = 12\frac{E_0}{E_1}\cdot\frac{1}{t^2 R^2} = \frac{c^2}{a^2\,t^2} = \frac{1}{a^2\,z_0^{\,2}}$$

$$x = \frac{z}{a} = \frac{1}{a}(z_0 + z') = \frac{z_0}{a}\left(1 + \frac{z'}{z_0}\right)$$

hence

$$\sqrt{2\,x} = \sqrt{\frac{2\,z_0}{a}}\left(1 + \frac{z'}{z_0}\right)^{\frac{1}{2}} = \sqrt{\frac{2\,z_0}{a}}\left(1 + \frac{z'}{2\,z_0}\right) = \sqrt{\frac{2\,z_0}{a}} + \frac{z'}{\sqrt{2\,z_0\,a}}$$

$$= \frac{\sqrt{2}}{a\,\mu} + \frac{\mu\,z'}{\sqrt{2}}$$

in which $\dfrac{\sqrt{2}}{a\,\mu}$ is a constant, so that α, β, γ, δ reduce to terms of the form

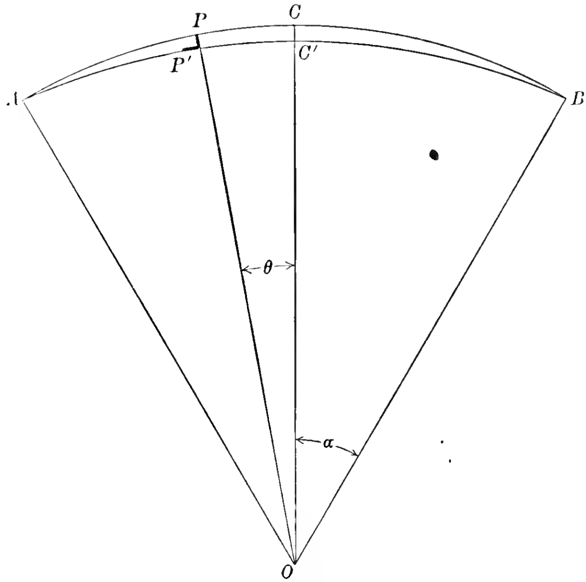
$$\cos.\ \frac{\mu\,z'}{\sqrt{2}}\ .\ \cosh.\ \frac{\mu\,z'}{\sqrt{2}}\ \text{etc.}$$

that is, when x is increased indefinitely and c decreased indefinitely, so as to keep the thickness of the dam constant, Michell's functions reduce to products of circular and hyperbolic functions and the solution degenerates into the form of Equation (16).

APPENDIX II.

DETERMINATION OF THE ELASTIC MODULUS FOR SEGMENTAL DAMS IN TERMS OF YOUNG'S MODULUS E_0 FOR THE MATERIAL USED IN THE DAMS.

Let $A\ C\ B$, Fig. 5, be a segment of a cylinder of unit height and of radius R, subject to a uniform compression T per unit area, free from bending moment and held so that the abutments A and B are fixed in position while the segment can slide freely on its base.



DEFORMATION OF A SEGMENTAL DAM
FIG. 5.

If E_0 is Young's Modulus for the material and f the elastic compression, *i. e.*, the ratio of the contraction in length to the original length of any part, then

$$T = E_0\, f \ldots\ldots\ldots\ldots\ldots\ldots\ldots (44)$$

Then, since T is constant throughout, f is constant. If, after deformation, the segment takes up the position $A\ C'\ B$ so that the point P goes to P' and C to C', if

$u =$ the normal displacement toward the axis O

$v =$ the tangential displacement in the direction θ increases, where θ is the angle $P\ O\ C$, C being the middle point of the segment,

then

$$f = \frac{1}{R}\left(-\frac{d\,v}{d\,\theta} + u\right) \ldots\ldots\ldots\ldots\ldots\ldots (45)$$

Now by hypothesis f is constant, hence from Equation (45)

$$-\frac{d\,v}{d\,\theta} + u = f\,R = \text{constant} \ldots\ldots\ldots\ldots\ldots (46)$$

Assume

$$u = u_0 - u_1 \cos.\,\theta \ldots\ldots\ldots\ldots\ldots\ldots\ldots (47)$$

which corresponds to a deformation symmetrical about $O\ C$. From Equations (46) and (47)

$$-v = \int_0^\theta (R\,f - u)\,d\,\theta = \int_0^\theta [(R\,f - u_0) - u_1 \cos.\,\theta\,]\,d\,\theta$$

$$= (R\,f - u_0)\,\theta - u_1 \sin.\,\theta \ldots\ldots\ldots\ldots\ldots\ldots (48)$$

When $\theta = 0$, $u = C\,C' = v$, say; and when $\theta = \pm\,\alpha$, $u = v = 0$ since A and B are fixed points. Hence, from Equations (47) and (48)

$$\left.\begin{aligned} (R\,f - u_0)\,\alpha - u_1 \sin.\,\alpha &= 0 \\ u_0 + u_1 \cos.\,\alpha &= 0 \\ u_0 + u_1 &= v \end{aligned}\right\} \ldots\ldots\ldots\ldots\ldots (49)$$

Solving Equation (49) for v

$$v = \frac{R\,f\,\alpha\,(1 - \cos.\,\alpha)}{\sin.\,\alpha - \alpha \cos.\,\alpha} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (50)$$

When α is small, approximately

$$\sin.\,\alpha = \alpha - \frac{\alpha^3}{\underline{|3}} = \alpha - \frac{\alpha^3}{6}$$

$$\cos.\,\alpha = 1 - \frac{\alpha^2}{\underline{|2}} = 1 - \frac{\alpha_2}{2}$$

Substituting in Equation (50)

$$v = \frac{R\,f\,\alpha \times \dfrac{\alpha^2}{2}}{\dfrac{\alpha^3}{3}} = \frac{3}{2}\,R\,f \ldots\ldots\ldots\ldots\ldots\ldots (51)$$

which is independent of α so long as α is small. When $\alpha = \frac{\pi}{3}$ (so that the angle $A\ O\ B$ is 120°) the coefficient of $R\,f$ is 1.528.... instead of 1.5, so that we may regard Equation (51) as practically true for all ordinary arched dams.

In the given case

$$f = \frac{T}{E_0}$$

from Equation (44), hence,

$$v = \frac{3}{2} \cdot \frac{R}{E_0} T \quad \text{.....................} (52)$$

Now, if a complete ring of radius R and centre O and of Young's Modulus E_0 be subjected to the same stress as above, then

$v = o$ throughout, and consequently

$$f = \frac{u}{R}$$

Hence,

$$T = E_0 \times f = E_0 \times \frac{u}{R}$$

so that

$$u = \frac{R}{E_0} T \quad \text{.......................} (53)$$

If T_1, E_0, and R be the same for the segment as for the complete ring, then the displacement of the middle point of the segment is 50% greater than the displacement of any point on the complete ring; that is to say, the displacement of the middle point of the segment is the same as it would be if the segment formed part of a complete cylinder of which the Young's Modulus had a value two-thirds of that which it actually has in the material.

If we suppose the dam divided up into horizontal layers in which T varies from layer to layer, and if we suppose that these layers are free to slide over one another; that is, if we neglect the twist of the surface due to the base being fixed and the displacements not being constant at all points of the arch layers, the displacement of the middle point C will be as given above, and we can obtain the solution for the segmental dam by using the Modulus $\frac{2}{3} E_0$ instead of E_0 in the solution for the complete cylinder.

APPENDIX III

NUMERICAL EXAMPLE OF CALCULATION OF STRESSES IN A DAM OF TRIANGULAR SECTION.

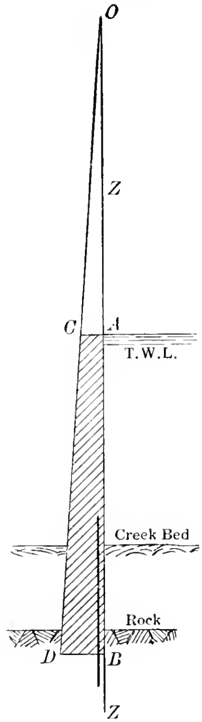
In the case of the Wooling dam, the leading dimensions, Fig. 6, are as follows:

Crest width, $A\ C = 2.20$ ft.
Base, $B\ D = 4.40$ ft.
Height, $A\ B = 33$ ft.

So that

$$c = \frac{2.2}{33} = \frac{1}{15}$$

The radius of the arch to the up-stream face is 135 ft. The angle of the sector is about 120° at crest level, so that E_0 is replaced by $\frac{2}{3}$ E throughout. The value adopted for E_1 was 2 600 000 lb. per sq. in. and that for E was 2 000 000 lb. per sq. in., the larger value being adopted for the vertical section to make a rough allowance for the vertical reinforcement and the value $\frac{2}{3}$ E being used to allow for the segmental form. Then



SECTION OF DAM OF TRIANGULAR SECTION, BASE ENCASTRÉE

FIG. 6.

$$a = c\ R \sqrt{\frac{1}{12} \cdot \frac{E_1}{\frac{2}{3} E}} = \frac{11}{3} \text{ nearly}$$

$$O\ A = l_1 = 15 \times 2.2 = 33 \text{ ft.}$$
$$O\ B = l_2 = 15 \times 4.4 = 66 \text{ ft.}$$

$$x = z \times \frac{1}{a} = \frac{3}{11} \times z$$

Hence, corresponding to A, $x = l_1' = 9$
and corresponding to B, $x = l_2' = 18$

Remembering that, for the segmental dam, $E_0 = \frac{2}{3}$ E, and calling

$$u = u' \frac{w\ R^2}{E_0\ c} = u' \frac{w\ R^2}{\frac{2}{3} E\ c}$$

$$A = A' \frac{w\ R^2}{E_0\ c}$$

etc.

Equation (43) may be written

$$u' = A' u_1 + B' u_2 + C' u_3 + D' u_4 + 1 - \frac{l'}{x} \ldots\ldots\ (54)$$

From which, by differentiation

$$\frac{d u'}{d x} = A' \frac{d u_1}{d x} + B' \frac{d u_2}{d x} + C' \frac{d u_3}{d x} + D' \frac{d u_4}{d x} + \frac{l'}{x^2} \ldots\ (55)$$

$$\frac{d^2 u'}{d x^2} = A' \frac{d^2 u_1}{d x^2} + B' \frac{d^2 u_2}{d x^2} + C' \frac{d^2 u_3}{d x^2} + D' \frac{d^2 u_4}{d x^2} - \frac{2 l'}{x^3} \ldots\ (56)$$

$$\frac{d^3 u'}{d x^3} = A' \frac{d^3 u_1}{d x^3} + B' \frac{d^3 u_2}{d x^3} + C' \frac{d^3 u_3}{d x^3} + D' \frac{d^3 u_4}{d x^3} + \frac{6 l'}{x^4} \ldots\ (57)$$

Case 1.—Dam Full to Crest Level—No Temperature Effect—Bottom Encastrée—Crest Free.

The end conditions for this case are, observing that since the water is at crest level, $l' = l_1'$

at $x = l_1' = 9$

$$M = F = 0 \qquad \frac{d^2 u'}{d x^2} = \frac{d^3 u'}{d x^3} = 0$$

at $x = l_2' = 18$

$$u' = \frac{d u'}{d x} = 0$$

Equations (54) to (57) thus give

at $x = l_1' = 9$

$$A' \frac{d^2 u_1}{d x^2} + B' \frac{d^2 u_2}{d x^2} + C' \frac{d^2 u_3}{d x^2} + D' \frac{d^2 u_4}{d x^2} = \frac{2 l_1'}{x^3}$$

$$= \frac{2 \times 9}{9^3} = + 0.024\,691 \ldots$$

$$A' \frac{d^3 u_1}{d x^3} + B' \frac{d^3 u_2}{d x^3} + C' \frac{d^3 u_3}{d x^3} + D' \frac{d^3 u_4}{d x^3} = - \frac{6 l_1'}{x^4}$$

$$= - \frac{6 \times 9}{9^4} = - 0.008\,230 \ldots$$

at $x = l_2' = 18$

$$A' u_1 + B' u_2 + C' u_3 + D' u_4 = -1 + \frac{l'}{x} = -1 + \frac{9}{18} = -0.500\,000 \ldots$$

$$A' \frac{d u_1}{d x} + B' \frac{d u_2}{d x} + C' \frac{d u_3}{d x} + D' \frac{d u_4}{d x} = - \frac{l'}{x^2}$$

$$= - \frac{9}{18^2} = - 0.027\,777 \ldots$$

TABLE 2.—*Continued.*

A'	B'	C'	D'	Term on Right	Sum of Coefficients + Term on Right
Hence, eliminating D',					
+ 0.000 534 837	....	+ 0.000 089 937	....	+ 0.032 473 402	+ 0.033 098 181
− 0.000 195 930	....	+ 0.000 184 456	....	− 0.009 138 353	− 0.009 149 823
From the second of these:					
− 1.0	....	+ 0.941 438 268	....	− 46.640 908 998	− 46.699 470 730
Multiplying each term by the coefficient of A' in the first of these:					
− 0.000 534 837	....	+ 0.000 503 516	....	− 0.024 945 284	− 0.024 976 605
Eliminating A'					
....	....	+ 0.000 593 453	....	+ 0.007 528 118	+ 0.008 121 576
....	....	1.0	....	+ 12.685 281 73	+ 13.685 281 73

Hence

$C' = +$ 12.685 281 73		+ 0.020 007 38
	+ 0.006 982 15	+ 4.233 746 43
+ 46.640 909 00	− 37.296 157 45	− 9.187 663 73
+ 11.942 409 66	− 6.828 083 08	+ 20.456 266 36
$A' = +$ 58.583 318 66	$D' = -$ 44.117 258 38	$B' = +$ 15.522 356 44

I	II	III	IV
+ 6.947 965	+ 3.059 530	+ 105.804 644	+ 134.567 12
− 6.773 796	+ 0.248 494	− 387.915 862	− 39.529 73
− 3.080 232	+ 0.724 064	− 229.606 919	− 0.735 30
+ 2.930 757	− 4.040 308	+ 511.218 134	− 94.329 87
+ 0.024 694	− 0.008 230	− 0.500 003	− 0.027 78

TABLE 2.—33-Foot Dam, Base Encastrée, Crest Free—Numerical Solution of Equation (43), Transformed as in Equation (54).

The Last Column is the Algebraic Sum of the Terms in the Other Columns and is Used for Checking Each Step.

A'	B'	C'	D'	Term on Right	Sum of Coefficients + Term on Right
$x = 9$					
+ 0.118 599 700	− 0.436 389 880	− 0.242 819 280	− 0.066 431 090	+ 0.024 691 358	− 0.602 349 192
+ 0.052 225 290	+ 0.016 008 770	+ 0.057 079 050	+ 0.091 581 370	− 0.008 230 453	+ 0.208 664 027
$x = 18$					
+ 1.806 054 110	− 24.990 784 340	− 18.100 261 750	− 11.587 713 130	− 0.500 000 000	− 53.372 705 110
+ 2.297 021 190	− 2.546 632 300	− 0.057 965 330	+ 2.138 162 360	− 0.027 777 778	+ 1.802 808 142
From the third of these:					
+ 0.072 268 805	− 1.0	− 0.724 277 468	− 0.463 679 456	− 0.020 007 375	− 2.135 695 477
Multiplying each of these by the coefficient of B' in Equations (1), (2), and (4)					
+ 0.031 537 375	− 0.436 389 880	− 0.316 067 357	− 0.202 345 022	− 0.008 731 016	− 0.931 995 903
+ 0.001 156 935	− 0.016 008 770	− 0.011 594 791	− 0.007 422 938	− 0.000 320 293	− 0.034 189 858
+ 0.184 042 073	− 2.546 632 300	− 1.844 468 394	− 1.180 821 080	− 0.050 951 428	− 5.438 831 128
Hence, eliminating B',					
+ 0.087 062 325	....	+ 0.073 248 077	+ 0.135 913 932	+ 0.033 422 374	+ 0.329 646 713
+ 0.053 382 225	....	+ 0.045 484 259	+ 0.084 158 432	− 0.008 550 746	+ 0.174 474 174
+ 2.112 979 117	....	+ 1.786 503 064	+ 3.318 983 440	+ 0.023 173 651	+ 7.241 639 270
From the third of these:					
+ 0.636 634 426	....	+ 0.538 268 146	1.0	+ 0.006 982 153	+ 2.181 884 726
Multiplying each of these numbers by the coefficient of D' in the first two:					
+ 0.086 527 488	....	+ 0.073 158 140	+ 0.135 913 932	+ 0.000 948 972	+ 0.296 548 532
+ 0.053 578 155	....	+ 0.045 299 803	+ 0.084 158 432	+ 0.000 587 607	+ 0.183 623 997

TABLE 3.—(*Continued*).

To Find $\frac{d^2 u'}{d x^2}$

Values of x, in Feet.

	9	10	11	12	13	14	15	16	17	18
$A' \frac{d^2 u_1}{d x^2}$	+ 6.947 965	+ 10.023 241	+ 13.070 437	+ 15.997 282	+ 18.708 875	+ 21.108 844	+ 23.101 505	+ 24.592 915	+ 25.492 754	+ 25.715 959
$B' \frac{d^2 u_2}{d x^2}$	− 6.773 796	− 6.373 854	− 5.664 587	− 4.641 148	− 3.305 337	− 1.665 845	+ 0.261 579	+ 2.454 049	+ 4.881 562	+ 7.507 104
$C' \frac{d^2 u_3}{d x^2}$	− 3.080 232	− 2.257 334	− 1.242 682	− 0.049 251	+ 1.304 832	+ 2.796 588	+ 4.398 471	+ 6.078 663	+ 7.801 396	+ 9.527 356
$D' \frac{d^2 u_4}{d x^2}$	+ 2.930 757	− 1.374 672	− 6.150 987	− 11.297 883	− 16.700 773	− 22.232 148	− 27.753 155	− 33.115 435	− 38.163 140	− 42.735 040
$-\frac{2 l'}{x^3}$	− 0.024 691	− 0.018 000	− 0.013 523	− 0.010 416	− 0.008 193	− 0.006 560	− 0.005 261	− 0.004 394	− 0.003 663	− 0.003 086
	+ 9.878 722 − 9.878 719	+ 10.023 241 − 10.023 860	+ 13.070 437 − 13.071 779	+ 15.997 282 − 15.998 698	+ 20.013 707 − 20.014 303	+ 23.905 432 − 23.904 553	+ 27.761 555 − 27.758 416	+ 33.125 627 − 33.119 829	+ 38.175 712 − 38.166 803	+ 42.750 419 − 42.738 126
$\frac{d^2 u'}{d x^2}$	+ 0.000 003	− 0.000 619	− 0.001 342	− 0.001 416	− 0.000 596	+ 0.000 879	+ 0.003 139	+ 0.005 798	+ 0.008 909	+ 0.012 293

TABLE 3.—33-Foot Dam, Base Encastrée, Segmental—Dam Just Full to Crest Level, No Overflow.

$c = \frac{1}{15}$ $A' = +\ 58.583\ 319$

$a = \frac{11}{3}$ $B' = +\ 15.522\ 356$

$R = 135$ ft. $C' = +\ 12.685\ 282$

$D' = -\ 44.117\ 258$

$$u' = A'\,u_1 + B'\,u_2 + C'\,u_3 + D'\,u_4 + \left(1 - \frac{l_1'}{x}\right)$$

$$u \div \frac{w\,R^2}{E_0\,c} = \frac{u}{0.089}$$

To Find u'

Values of x, in Feet.

	9	10	11	12	13	14	15	16	17	18
$A'\,u_1$	− 211.802 57	− 241.944 22	− 262.065 18	− 269.125 80	− 260.206 59	− 232.604 87	− 183.928 18	− 112.191 75	− 15.911 72	+ 105.804 64
$B'\,u_2$	+ 3.032 86	− 25.937 62	− 61.256 17	− 102.214 08	− 147.785 10	− 196.637 10	− 247.130 96	− 297.341 09	− 345.077 54	− 387.915 86
$C'\,u_3$	− 36.789 06	− 60.907 250	− 87.266 76	− 114.854 06	− 142.477 24	− 168.783 99	− 192.285 09	− 211.381 02	− 224.391 84	− 229.606 91
$D'\,u_4$	+ 245.735 03	+ 328.844 84	+ 410.540 75	+ 486.054 72	+ 550.249 49	+ 597.732 46	+ 622.984 57	+ 620.496 43	+ 584.919 05	+ 511.218 13
$1 - \frac{l'}{x^4}$	0.	+ 0.100 000	+ 0.181 82	+ 0.250 00	+ 0.307 70	+ 0.357 15	+ 0.400 00	+ 0.437 50	+ 0.470 59	+ 0.500 00
	+ 248.767 89	+ 328.944 84	+ 410.722 57	+ 486.304 72	+ 550.557 19	+ 598.089 61	+ 623.384 57	+ 620.933 93	+ 585.389 64	+ 617.522 77
	− 248.591 63	− 328.789 09	− 410.588 11	− 486.193 94	− 550.468 93	− 598.025 96	− 623.344 23	− 620.913 86	− 585.384 10	− 617.522 77
u'	+ 0.176 26	+ 0.155 75	+ 0.134 46	+ 0.110 78	+ 0.088 26	+ 0.063 65	+ 0.040 34	+ 0.020 07	+ 0.005 54	+ 0.000 00

Substituting from the tables and solving according to the tabular form, Table 2.

$$A' = +\ 58.583\ 319$$
$$B' = +\ 15.522\ 356$$
$$C' = +\ 12.685\ 282$$
$$D' = -\ 44.117\ 258.$$

Observing that

$$M = C_1 \frac{d^2 u}{d z^2} = w\ a^3\ x^3 \frac{d^2 u'}{d x^2}$$

where $a = \frac{11}{3}$ nearly, the bending moments at $x = 9, 10 \ldots\ldots 18$ can be found. Again, observing that by Equation (48)

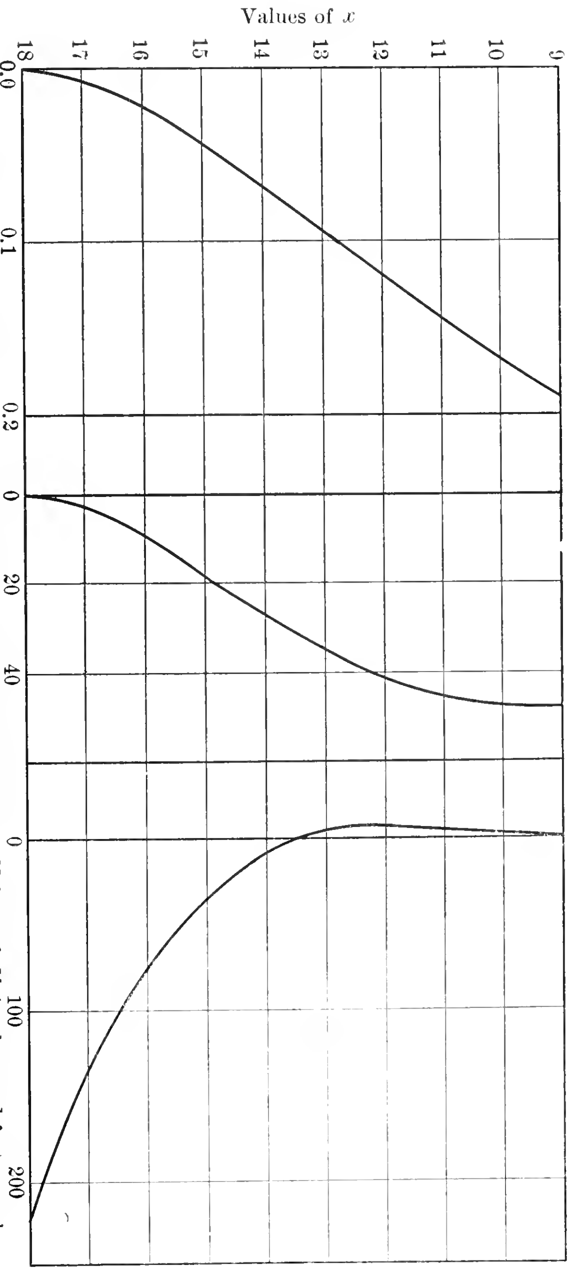
$$T = \frac{2}{3} E \times \frac{t}{R} \times u = \frac{2}{3} E \times \frac{c\,z}{R} \times u' \times \frac{w\ R^3}{\frac{2}{3} E\ c} = w\ R^2 \times z\ u'$$

the arch thrust at $x = 9,\ 10 \ldots\ldots 18$ can be found. Diagrams for the thrust and bending moment are given in Figs. 8 and 9.

TABLE 4.—33-Foot Dam, Base Encastrée, Crest Free—Displacements (u), Thrusts (T), and Bending Moments (M).

$$u = 0.089\ u'$$
$$T = w\ a\ R\ x\ u' = 31\ 000\ x\ u'$$
$$M = w\ a^3\ x^3 \frac{d^2 u'}{d x^2} = 3080\ x^3 \frac{d^2 u'}{d x^2}$$
$$E_0 = \frac{2}{3} E, \text{ where } E \text{ is Young's Modulus for concrete}$$
$$d = \text{depth below crest level, in feet}$$

x	z, in feet.	d, in feet.	u, in inches.	T, in pounds per foot height.	M, in foot pounds per foot width.
9	33.0	0	0.188	49 000	0
10	36.6	3.6	0.166	48 200	− 1 900
11	40.3	7.3	0.143	45 800	− 5 500
12	44.0	11.0	0.118	41 100	− 7 500
13	47.6	14.6	0.093	35 500	− 4 000
14	51.3	18.3	0.068	27 600	+ 7 400
15	55.0	22.0	0.042	18 700	+ 32 600
16	58.6	25.6	0.021	9 900	+ 73 200
17	62.3	29.3	0.006	2 900	+134 800
18	66.0	33.0	0.000	0	+220 900



Values of u, in inches.

FIG. 7.—DIAGRAM SHOWING DISPLACEMENTS,

Values of T, in thousand pounds.

FIG. 8.—DIAGRAM SHOWING ARCH THRUST, T

Values of M, in thousand foot-pounds.

FIG. 9.—DIAGRAM SHOWING BENDING MOMENTS M

FIGS. 7, 8, 9.—DISPLACEMENT, THRUST AND BENDING MOMENT, 33-FOOT DAM, BASE ENCASTRÉE, CREST FREE.

APPENDIX IV.

NUMERICAL EXAMPLE OF CALCULATION OF TEMPERATURE STRESSES, BASE ENCASTREE, CREST FREE.

To deal with this case, suppose the dam empty and proceed as in Section 6, under the heading "Proposed Method of Design, Using Michell's Functions". Put $w = o$ in Equation (43), which then becomes simply

$$u = A\, u_1 + B\, u_2 + C\, u_3 + D\, u_4 \qquad (58)$$

Let

θ = the anticipated rise of temperature above the mean temperature during the construction of the dam;

e = the coefficient of expansion of the concrete

The displacement at the centre is v towards the axis of the cylinder, where

$$v = e\, R\, \theta \qquad (59)$$

Equations (54) to (57) are now replaced, when $x = l_1 = 9$, by

$$A \frac{d^2 u_1}{d\, x^2} + B \frac{d^2 u_2}{d\, x^2} + C \frac{d^2 u_3}{d\, x^2} + D \frac{d^2 u_4}{d\, x^2} = 0$$

$$A \frac{d^3 u_1}{d\, x^3} + B \frac{d^3 u_2}{d\, x^3} + C \frac{d^3 u_3}{d\, x^3} + D \frac{d^3 u_4}{d\, x^3} = 0$$

and when $x = l_2 = 18$

$$A\, u_1 + B\, u_2 + C\, u_3 + D\, u_4 = v = e\, R\, \theta$$

$$A \frac{d\, u_1}{d\, x} + B \frac{d\, u_2}{d\, x} + C \frac{d\, u_3}{d\, x} + D \frac{d\, u_4}{d\, x} = 0$$

or, calling $A \div e\, R\, \theta = A''$, etc., these become

when $x = l_1 = 9$

$$\left.\begin{aligned} & A'' \frac{d^2 u_1}{d\, x_2} + B'' \frac{d^2 u_2}{d\, x^2} + C'' \frac{d^2 u_3}{d\, x^2} + D'' \frac{d^2 u_4}{d\, x^2} = 0 \\ & A'' \frac{d^3 u_1}{d\, x^3} + B'' \frac{d^3 u_2}{d\, x^3} + C'' \frac{d^3 u_3}{d\, x^3} + D'' \frac{d^3 u_4}{d\, x^3} = 0 \\ & \text{when } x = l_2 = 18 \\ & A''\, u_1 + B'' + u_2 + C''\, u_3 + D''\, u_4 = 1 \\ & A'' \frac{d\, u_1}{d\, x} + B'' \frac{d\, u_2}{d\, x} = C'' \frac{d\, u_3}{d\, x} + D'' \frac{d\, u_4}{d\, x} = 0 \end{aligned}\right\} \qquad (60)$$

The coefficients on the left-hand side of Equation (60) are the same as for the case of the dam full, so that the numerical work for the solution is confined to the necessary alteration of the quantities on the right-hand side. Solving,

$$A'' = -\,23.575\,513$$
$$B'' = -\quad 5.099\,821$$
$$C'' = -\quad 7.560\,851$$
$$D'' = +\,19.048\,045$$

Observing that $A = A'' \times e\, R\, \theta$, u is determined, and therefore T and M, throughout for any specified temperature range θ. These must be superposed on the former results.

For the bending moments

$$M = C_1 \frac{d^2 u}{d z^2}$$

but since

$$z = a\, x$$

$$C_1 = \frac{1}{12} E_1\, t^3$$

$$t = c\, z$$

$$a^2 = \frac{1}{12} \cdot \frac{E_1}{E_0} \cdot c^2\, R^2$$

Therefore,

$$M = \frac{E_0\, c^3}{c^2\, R^2} z^3 \frac{d^2 u}{d x^2} = \frac{E_0\, c\, a^3}{R^2} x^3 \frac{d^3 u}{d x^2}$$

$$= \frac{E_0\, \theta\, e\, c\, a^3}{R} x^3 \frac{d^2 u''}{d x^2}$$

where

$$u'' = A''\, u_1 + B''\, u_2 + C''\, u_3 + D''\, u_4$$

In order to find the actual displacements, it is to be observed that the rise of temperature θ was supposed to have caused the dam to expand freely and uniformly throughout, so that the displacement at all points was $v = -\, e\, R\, \theta$. By imagining the dam forcibly brought back so that its base occupies the original position, by making $u'' = 1$ at all points of the base, the corresponding displacements u'' at all points of the dam were found. It is these which must be used for finding the stresses, but to find the displacements, deduct 1 from u'' at all points.

TABLE 5.—(*Continued.*)

$$\frac{d^2 u''}{d x^2} = A'' \frac{d^2 u_1}{d x^2} + B'' \frac{d^2 u_2}{d x^2} + C'' \frac{d^2 u_3}{d x^2} + D'' \frac{d^2 u_4}{d x^2}$$

VALUES OF x, IN FEET.

	9	10	11	12	13	14	15	16	17	18
$A'' \frac{d^2 u_1}{d x^2}$	− 2.796 049	− 4.033 623	− 5.259 896	− 6.437 739	− 7.528 934	− 8.494 770	− 9.296 672	− 9.896 856	− 10.258 975	− 10.348 799
$B'' \frac{d^2 u_2}{d x^2}$	+ 2.225 510	+ 2.094 110	+ 1.861 083	+ 1.524 835	+ 1.085 958	+ 0.547 308	− 0.085 941	− 0.806 270	− 1.603 822	− 2.466 436
$C'' \frac{d^2 u_3}{d x^2}$	+ 1.835 921	+ 1.345 446	+ 0.740 680	+ 0.029 355	− 0.777 723	− 1.666 860	− 2.621 635	− 3.623 086	− 4.649 892	− 5.678 620
$D'' \frac{d^2 u_4}{d x^2}$	− 1.265 382	+ 0.593 528	+ 2.655 747	+ 4.877 968	+ 7.210 718	+ 9.598 940	+ 11.932 686	+ 14.297 905	+ 16.477 297	+ 18 451 257
	+ 4.061 431 − 4.061 431	+ 4.033 074 − 4.033 623	+ 5.257 510 − 5.259 896	+ 6.432 158 − 6.437 739	+ 8.296 676 − 8.306 657	+ 10.146 248 − 10.161 630	+ 11.982 686 − 12.004 248	+ 14.297 905 − 15.326 212	+ 16.477 297 − 16.512 689	+ 18.451 257 − 18.493 855
$\frac{d^2 u''}{d x^2}$	+ 0.000 000	− 0.000 549	− 0.002 386	− 0.005 581	− 0.009 981	− 0.015 382	− 0.021 562	− 0.028 307	− 0.035 392	− 0.042 598

TABLE 5.—Temperature Effect, 33-Foot Dam, Base Encastrée.

where

$$u'' = A'' u_1 + B'' u_2 + C'' u_3 + D'' u_4$$
$$A'' = A \div e R \theta$$
$$u'' = u \div e R \theta$$

$$A'' = -23.575\ 513$$
$$B'' = -\ \ 5.099\ 821$$
$$C'' = -\ \ 7.560\ 851$$
$$D'' = +19.048\ 045$$

The deduction of 1 is made in order to represent the fixed base, leaving the rest of the cylinder expanded by the rise of temperature.

Values of x, in Feet.

	9	10	11	12	13	14	15	16	17	18
$A'' u_1$	+ 85.235 093	+ 97.364 942	+ 105.462 106	+ 108.303 405	+ 104.714 182	+ 93.606 470	+ 74.017 659	+ 45.148 984	+ 6.403 305	— 42.578 652
$B'' u_2$	— 0.996 437	+ 8.521 724	+ 20.125 517	+ 33.581 782	+ 48.554 322	+ 64.604 493	+ 81.194 080	+ 97.690 462	+ 113.374 127	+ 127.448 538
$C'' u_3$	+ 21.927 503	+ 36.302 750	+ 52.013 907	+ 68.456 847	+ 84.921 154	+ 100.600 885	+ 114.608 285	+ 125.990 141	+ 133.746 796	+ 136.853 391
$D'' u_4$	— 106.098 437	— 141.981 910	— 177.254 882	— 209.858 750	— 237.575 408	— 258.076 723	— 268.979 443	— 267.905 191	— 252.544 314	— 220.723 288
	+ 107.162 596	+ 142.189 416	+ 177.601 530	+ 210.342 034	+ 238.189 658	+ 258.811 848	+ 269.820 024	+ 268.829 587	+ 253.524 228	+ 264.301 929
	— 107.094 874	— 141.981 910	— 177.254 882	— 209.858 750	— 237.575 408	— 258.076 723	— 268.979 443	— 267.905 191	— 252.544 314	— 263.301 930
u''	+ 0.067 722	+ 0.207 506	+ 0.346 648	+ 0.483 284	+ 0.614 250	+ 0.735 125	+ 0.840 581	+ 0.924 396	+ 0.979 914	+ 0.999 999
$(u'' - 1)$	— 0.932 278	— 0.792 494	— 0.653 352	— 0.516 716	— 0.385 750	— 0.264 875	— 0.159 419	— 0.075 604	— 0.020 086	— 0.000 001

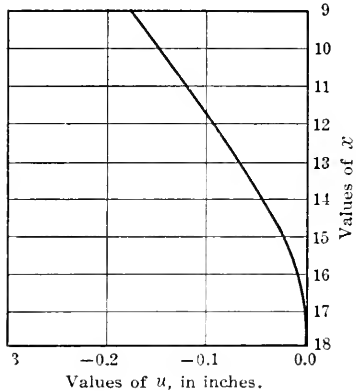


FIG 10.—DISPLACEMENT CURVE, u

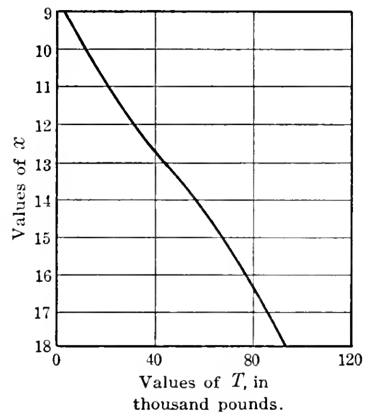


FIG. 11.—ARCH THRUST T

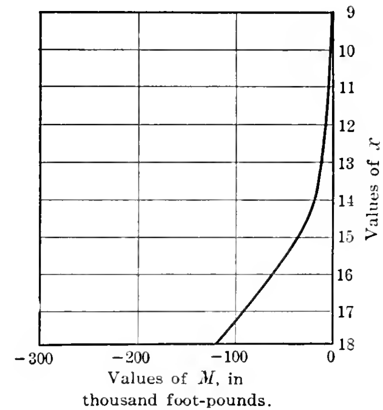


FIG. 12.—BENDING MOMENT M

FIGS. 10, 11, 12.—DISPLACEMENT, THRUST AND BENDING MOMENT DUE TO TEMPERATURE.

To find the thrust

$$T = \frac{E_0 t}{R} u = \frac{E_0 c a}{R} x u = E_0 \theta e c a \times x u$$

For example, if $\theta = 20°$ Fahr., $e = 0.000\,005\,5$ $R = 135$, then $e R \theta = 0.015$ ft., say, $E_0 \theta e c a = \frac{2}{3} (288 \times 10^6) \times 20 \times .000\,005\,5 \times \frac{1}{15} \times \frac{11}{3} = 5160$, say

$$\frac{E_0 \theta e c a^3}{R} = 5160 \times \frac{a^2}{R} = 5160 \times \left(\frac{11}{3}\right)^2 \times \frac{1}{135} = 514, \text{ say.}$$

TABLE 6.—Temperature Effect, Base Encastrée, Crest Free, Dam Empty.

x	z, in feet.	d, in feet.	u, in inches.	T. in pounds per foot height.	M. in foot pounds per foot width.
9	33.0	0	— 0.168	3 150	0
10	36.6	3.6	— 0.143	10 700	— 300
11	40.3	7.3	— 0.118	19 700	— 1 600
12	44.0	11.0	— 0.093	29 900	— 5 000
13	47.6	14.6	— 0.069	41 200	— 11 300
14	51.3	18.3	— 0.048	53 100	— 21 700
15	55.0	22.0	— 0.029	65 100	— 37 400
16	58.6	25.6	— 0.013	76 300	— 59 600
17	62.3	29.3	— 0.004	86 000	— 89 400
18	66.0	33.0	— 0.00	92 900	—127 700

APPENDIX V.

DEFLECTIONS IN THE WOOLING DAM.

The deflection observations for the Wooling Dam were somewhat rough, as there was considerable oscillation in the plumb line on account of wind. In making the observations, a plumb line was hung from a small triangular notch in an angle iron built into the concrete at crest level, and the distances from the plumb line to the wall were measured at each 5 ft. interval on June 10th, 1916, when the dam was empty, and again on March 28th, 1917, when the dam was nearly full. A comparison of calculated with observed deflections is given in Table 7.

TABLE 7.—Comparison of Calculated and Observed Deflections in the Wooling Dam.

Depth below crest.	Displacement, in inches, due to water pressure—dam full —, + when down stream.	Displacement, in inches, due to rise of temperature of 20° Fahr.—dam empty.	Resultant—two preceding columns.	Depth below crest, in feet.	Observed displacement, in inches, water 1 ft. 8 in. below crest March 28th, 1917
0	+ 0.19 inch	— 0.17 inch	+ 0.02 inch	0	0
3 ft. 8 in.	+ 0.17	— 0.14	+ 0.03	5	+ $\frac{1}{16}$
7 ft. 4 in.	+ 0.14	— 0.11	+ 0.03		
11 ft. 0 in.	+ 0.12	— 0.09	+ 0.03	10	+ $\frac{1}{8}$
14 ft. 8 in.	+ 0.09	— 0.07	+ 0.02	15	+ $\frac{1}{8}$
18 ft. 4 in.	+ 0.07	— 0.05	+ 0.02		
22 ft. 0 in.	+ 0.04	— 0.03	+ 0.02	20	+ $\frac{1}{8}$
25 ft. 8 in.	+ 0.02	— 0.01	+ 0.01	23*	0
29 ft. 4 in.	+ 0.01	— 0.00	+ 0.01		
33 ft. 0 in.	+ 0.00	— 0.00	+ 0.00		

* Ground level is 23 feet below crest.

The temperature was not recorded during construction but most of the work was done during the months of March to June, 1916. Table 8 gives the official records of the mean monthly temperature at Macedon, about 3 miles from the dam and at about the same height above sea level. The temperature of the water was observed on November 2d, 1916, to be 13° Cent. = 55° Fahr., and the estimated temperature on March 28th, 1917, was 60° Fahr. The water was then cool, but not cold.

TABLE 8.—Mean Temperature, in Degrees Fahrenheit, at Macedon, Victoria, Australia.

January	65.1	May	48.7	September	48.8
February	64.7	June	45.1	October	53.6
March	60.8	July	43.2	November	58.7
April	54.7	August	45.4	December	63.0

APPENDIX VI.

ACKNOWLEDGMENTS OF ASSISTANCE.

It is desired to acknowledge the assistance given in the investigation by Mr. J. H. Michell (London) who reduced Equation (30) to the general form, Equation (34), and gave the four series solutions of this equation which have been tabulated as Michell's Functions. Acknowledgment must also be made of the assistance given by my assistants Mr. A. French* and Mr. H. M. Sherrard who carried out the laborious work of tabulating Michell's Functions and carefully checked every result; also of the courtesy of Dr. Baldwin, the Acting Government Astronomer of Victoria (Australia), for his assistance in suggesting the best method of calculating the tables and for allowing the use of his 8-figure calculating machine. Finally, mention must be made of the valuable suggestions as to arrangement of subject matter and as to points requiring further elucidation made by the Publication Committee of the Society.

* Died in active service.

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INSTITUTED 1852

PAPERS AND DISCUSSIONS

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NOTES ON TUNNEL LINING

By S. Johannesson* and B. H. M. Hewett,* Members, Am. Soc. C. E.

To be Presented April 21st, 1920.

Synopsis.

In the construction of tunnels, particularly under compressed air in soft soil, the engineer has met a number of difficulties connected with the lining, often obscure in their origin, which for that reason have caused anxiety, delay and unforeseen expense.

In this paper the more important of these difficulties are stated and methods of avoiding them suggested. These suggestions are discussed both from a practical and theoretical point of view. It is the purpose first to attempt to determine the causes for the distortions and displacements common to tunnel linings, and second, to suggest how they may be avoided by the modification of existing practice. The subject, however, is so extensive that, in order to keep the paper within reasonable limits, a general outline only will be presented.

For the sake of convenience, the paper is divided into sections as follows:

1.—Behavior of tunnel lining during construction.

2.—Determination of stresses in tunnel linings.

3.—Conditions for stable equilibrium.

4.—Stresses in tunnel lining during construction.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

* New York City.

5.—North River silt.
6.—Ruling requirements for the erection and design of tunnel lining.
7.—Design of tunnel lining.
8.—Materials of construction.
9.—Secondary lining.
10.—Cost of tunnel linings.
11.—Conclusions.

1.—Behavior of Tunnel Lining During Construction.

A common experience when building a shield-driven cast-iron lined tunnel is that, although it may be possible to erect the lining true to line, level and shape, it is difficult and even impossible to keep it so during the construction period.

Immediately after the shield has left a newly erected ring of the lining the ring may move up or down and as likely as not it will change its shape, sometimes in one direction and sometimes in another. If the deformation threatens to become excessive, the tunnel has to be braced. Afterward it may be found that this bracing, although carefully placed, becomes loose and ineffective because the lining has started to deform in another direction. Then the bolts may have to be retightened and the water-proofing of the joints and the bolt holes may have to be done again every time the lining changes its shape.

The up or down movements may be even more serious. In the Pennsylvania Railroad Tunnels under the North River at New York City at one time the tunnel started to rise suddenly immediately behind the shield for some at that time unexplained reason, and rose as much as 12 in. above the level at which it was erected. This naturally caused much concern. The work was closed down for about one month and the tunnel lining redesigned.

In another tunnel under the East River at New York City, the lining settled at one place to such an extent that there was not clearance enough left for the traffic to pass through, and thus necessitated the reconstruction of this part of the tunnel.

It is evident that to take care of these distortions and displacements is expensive both in money and time and adds greatly to the cost of the finished structure. Therefore they should, if possible, be avoided.

2.—Determination of Stresses in Tunnel Linings.

The primary function of the lining of a tunnel is to support the surrounding soil. In addition to this, it is often necessary and nearly always desirable that the lining should be capable of preventing the infiltration of water which may be present in the ground under a considerable head. Furthermore, when the tunnel is constructed by the shield method the lining must be able to support the thrust of the shield rams.

The lining of a tunnel is subject to stresses caused by the external forces, and only when these are known is it possible to determine the stresses in the lining.

Assuming material with small angle of repose, the vertical forces on the upper half of the tunnel are the weight of the soil, the weight of the lining and the possible live loads above the tunnel within two vertical planes tangent to the sides of the tunnel. The force on any given area of the tunnel is that portion of the forces which is vertically above the area.

The vertical forces on the lower half of the tunnel are equal to the vertical forces on the upper half of the lining, plus the weight of the tunnel and its contents. The distribution of these forces is uncertain, but can generally be assumed with sufficient accuracy. The horizontal forces, which must be balanced on the two sides of the tunnel, as the tunnel otherwise will be in sidewise motion, can be determined by means of Rankine's "Theory of Conjugate Stresses."

Let p = the vertical load on a unit of horizontal surface within the ground;

p_1 = the horizontal soil pressure on a unit of vertical surface at the same depth; and

α = the angle of repose of the soil.

Then, in accordance with Rankine's theory,

$$p_1 = p \frac{1 - \sin. \alpha}{1 + \sin. \alpha} \qquad (1)$$

This formula represents the active horizontal pressure of the soil. The soil is, however, able to resist a greater horizontal force, represented by

$$p_2 = p \frac{1 + \sin. \alpha}{1 - \sin. \alpha} \qquad (2)$$

This force p_2 is called the passive pressure of the soil.

The horizontal pressure on the tunnel is always at least equal to the active pressure p_1, but if the condition of the internal stresses in the tunnel lining should so require, a greater horizontal pressure will be developed of such a magnitude as will be required to provide the necessary equilibrium, but under no circumstances greater than p_2.

In order to find the stresses in the tunnel lining it is necessary to determine which value of the horizontal force, between the limits of p_1 and p_2, is in action. This can be determined by the fact that such a horizontal force is in action as will produce the least internal work.

The least internal work will be produced if the stress polygon coincides with the neutral axis of the tunnel lining. To find if this coincidence is possible, it is necessary, first, to determine whether a horizontal force which would produce the coincidence might be applied, and, second, whether such a horizontal force would come within the limits of the active and passive forces. If it does, the stress polygon will coincide with the neutral axis, and the tunnel lining will be in direct compression only.

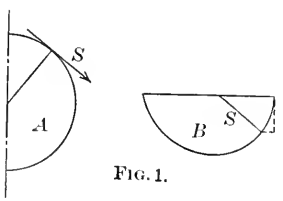


FIG. 1.

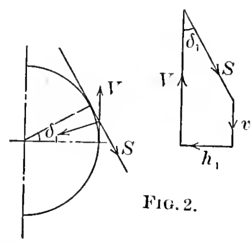


FIG. 2.

In Fig. 1, A represents half the circumference of a tunnel, and B a force diagram for the tunnel. It will be seen that, if the direction of the force S is parallel to the tangent to the corresponding point of the circumference, the stress polygon will follow the neutral axis; it will be seen, also, that for any given vertical force there is always a horizontal force which will produce the desired results. The value of this horizontal force can be determined as follows:

The forces acting on the portion of the lining between the horizontal radius and a radius forming an angle δ_1 with the horizontal are the tangential stress, S, in the lining, the vertical stress, V, and the external forces with a vertical component v_1 and a horizontal component h_1.

Fig. 2 shows that

$$h_1 = (V - v_1) \text{ tan. } \delta_1 \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where V is the vertical load on one-half of the tunnel, and v_1 is the vertical load on the portion of the lining considered.

The horizontal force on a portion of the lining between two radii forming angles of δ_1 and δ_2, respectively, with the horizontal is

$$h_1 - h_2 = (V - v_1) \tan. \delta_1 - (V - v_2) \tan. \delta_2 \qquad (4)$$

In a circular tunnel with radius r, the horizontal pressure per unit of area is

$$p_i = \frac{h_1 - h_2}{r\,(\sin. \delta_2 - \sin. \delta_1)}$$

or

$$p_i = \frac{(V - v_1) \tan. \delta_1 - (V - v_2) \tan. \delta_2}{r\,(\sin. \delta_2 - \sin. \delta_1)} \qquad (5)$$

This pressure p_i is, in the following, termed the ideal pressure.

In a more convenient form for use, p_i may be expressed by the following equation, which gives an approximate value only, and in which w represents the unit weight of the soil, and δ the radial angle.

$$p_i = p_1 + 0.11\,(2 + \sin. \delta)\,(1 - 2 \sin. \delta)\,w\,r \qquad (6)$$

If $p_1 < p_i < p_2$, the tunnel lining will be subject to direct compression stresses only.

Assuming that the vertical forces on the lower half of the tunnel are distributed in the same way as they are on the upper half, which is near enough for the present purpose, in order to obtain the condition that the lining may be in direct compression only the active horizontal pressure at the bottom of the tunnel should be no larger than the ideal pressure, p_i, at the top of the tunnel.

In order to determine what angles of repose would produce such pressures under certain given conditions, the pressures, p_i, have been determined for circular tunnels with diameters of 12, 18, 24, 30 and 36 ft., respectively, and with the assumption that the vertical pressure at the top of the tunnel is 4 000 lb. per sq. ft. and that the weight of the material is 120 lb. per cu. ft. The results are plotted on Fig. 3, and by applying Equation (1) it is found that, under the assumptions made, direct compressive stresses only will occur when the angle of repose is not less than the values given in the following table:

Diameter of tunnel, in feet.	12	18	24	30	36
Angle of repose...........	10° 30′	14° 30′	18° 30′	22° 0′	25° 30′

If the vertical pressure at the top of the tunnel is less, the angles will be greater, and if the weight per cubic foot of the material is less, the angles will be less; but generally it may be said, that in order to obtain direct compressive stresses only in the lining of a circular tunnel, the diameter of the tunnel must be limited to a certain value which varies directly as the value of the angle of repose. This limiting value of the diameter is about 12 ft. when the angle of repose is 10°, and about 43 ft. when the angle of repose is 30 degrees.

If the angle of repose of the soil is less than as determined above, the lining will be subject to bending stresses in addition to the direct compression stresses. These bending stresses may be determined by means of a stress diagram. It is evident that the horizontal forces to apply are the active horizontal pressures, when they are larger than the ideal pressures.

In Equation (5) the term r (sin. δ_2 — sin. δ_1) represents the vertical projection of the area of the tunnel lining upon which the horizontal pressure is acting. If this area is reduced without similarly reducing the horizontal projection of the area, the value of p_i will increase. Such a reduction can be accomplished by making the tunnel elliptical, with the major axis horizontal. The ratio between the horizontal and vertical diameters of the ellipse can be found as follows:

First, determine the maximum passive horizontal pressure per unit of area at the top of the tunnel, and the active horizontal pressure per unit of area at the bottom. If the latter is equal to the former, an elliptical tunnel may be constructed which will be subject to compressive stresses only, and the ratio between the horizontal and vertical diameters of the ellipse will be equal to the square root of the ratio between the active pressure at the bottom of the tunnel and the ideal pressure at the top of the tunnel.

If the maximum passive horizontal pressure at the top of the tunnel is less than the active horizontal pressure at the bottom of the tunnel the lining will be subject to bending stresses which, however, will be as small as possible if the ratio between the horizontal and vertical diameters of the ellipse is equal to the square root of the ratio between the maximum passive pressure at the top of the tunnel and the corresponding ideal pressure.

If the maximum passive horizontal pressure at the top of the tunnel is greater than the active horizontal pressure at the bottom of the tun-

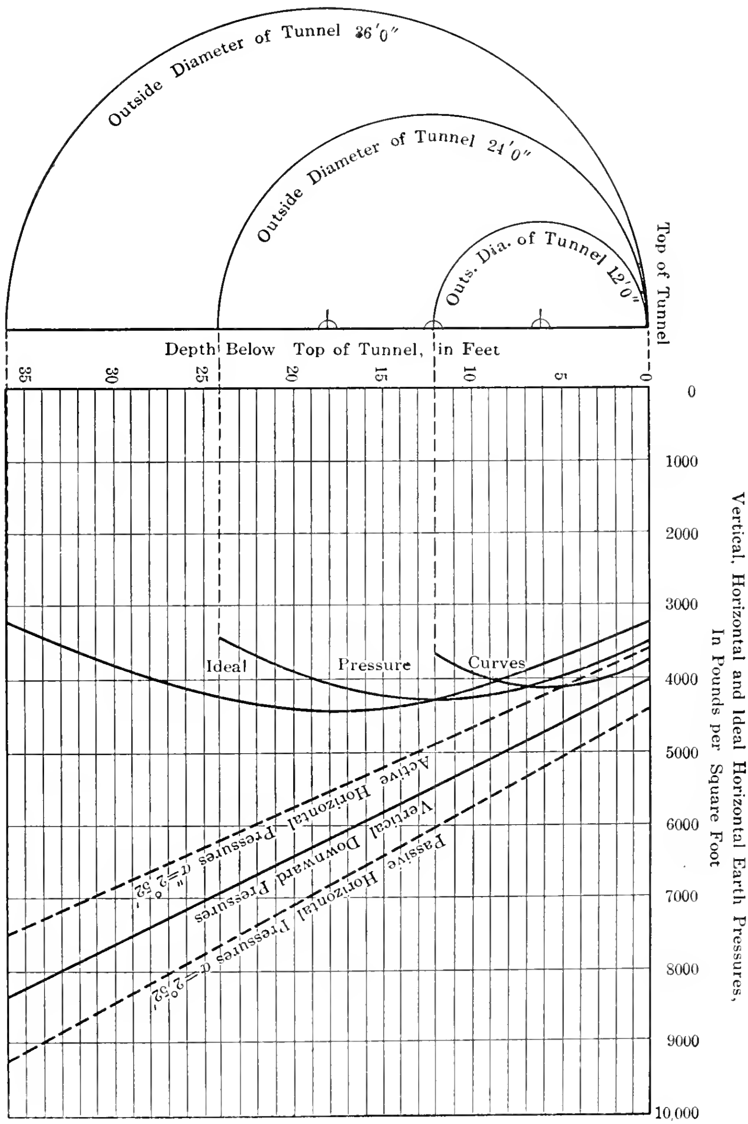

Outside Diameter of Tunnel 36′0″
Outside Diameter of Tunnel 24′0″
Outs. Dia. of Tunnel 12′0″
Top of Tunnel
Depth Below Top of Tunnel, in Feet
35
30
25
20
15
10
5
0
Ideal Pressure Curves
Active Horizontal Pressures α=2°52′
Vertical Downward Pressures
Passive Horizontal Pressures α=2°52′
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
Vertical, Horizontal and Ideal Horizontal Earth Pressures,
In Pounds per Square Foot

FIG. 3.

nel, elliptical tunnels subject to direct compressive stresses only may be designed, with the ratio between the horizontal and vertical diameters varying between the square root of the ratio which the active bottom horizontal pressure bears to the top ideal pressure and the square root of the ratio which the maximum passive top pressure bears to the top ideal pressure.

The ratio between the vertical and the horizontal diameter in soil with an angle of repose of 2° 52′, weighing 120 lb. per cu. ft. and when the pressure at the top of the tunnel is 4 000 lb. is approximately as 9 to 10.

It may be stated, therefore, that in soil with an angle of repose producing bending stresses in a circular tunnel, it is possible to reduce and sometimes to eliminate the bending stress by making the shape of the tunnel elliptical.

3.—Conditions for Stable Equilibrium.

If the angle of repose is small, the distribution of the vertical forces on the lower half of the tunnel may be different from that assumed, because the active vertical forces become effective. In that case the distribution may be assumed to be as follows: Determine the upward forces which, in accordance with Rankine's theory are, per unit of area:

$$p_3 = p \left(\frac{1 - \sin. \alpha}{1 + \sin. \alpha}\right)^2 \qquad (7)$$

and distribute the difference between the upward and downward forces, including the weight of the tunnel, uniformly over the horizontal diameter.

If this difference is less than the weight of the tunnel, passive upward vertical forces are developed, and according to Rankine the maximum value of these is:

$$p_4 = p \left(\frac{1 + \sin. \alpha}{1 - \sin. \alpha}\right)^2 \qquad (8)$$

It may be said, therefore, that if the total vertical downward forces are less than or equal to the total maximum passive upward forces as determined by Equation (8), the tunnel will not sink.

If the total active upward forces as determined by Equation (7) are greater than the total downward forces, it does not necessarily follow that the tunnel will rise, because the resistance to upward motion is greater than the total downward load; for, in addition to overcoming

the resistance of the load, the frictional resistance on two vertical planes from the top of the soil to the bottom of the tunnel has to be overcome.

Let D = the distance from the top of the soil to the bottom of the tunnel;

q_1 = the unit horizontal pressure at the top of soil, and

q_2 = the unit horizontal pressure at the bottom of the tunnel.

Then the frictional resistance will be

$$F = (q_1 + q_2)\ D \tan. \alpha \ldots\ldots\ldots\ldots (9)$$

It follows, therefore, that if the sum of the total downward load and the frictional resistance is greater than the total active upward force, the tunnel will not rise.

4.—Stresses in Tunnel Lining During Construction.

During the period of construction, the lining is subject to external forces and to conditions different from those which exist when this period of disturbance is past. In order to secure the safety of the tunnel during this period and to carry out the work of construction economically, it is necessary to determine in advance the stresses to which the lining may be subjected during the construction. This is particularly true when the tunnel is driven by the shield method through water-bearing ground.

Since the tunnel lining is used as the abutment for the shield rams, the stresses in the lining are influenced by the pressures exerted on it by the rams. These ram stresses consist of direct compression parallel to the axis of the tunnel, when the line of pressure coincides with the neutral axis of the skin of the lining. If not, additional weight of lining material is needed to take up stresses which are wholly temporary and constructional and which do not exist after the driving period is over. It is ordinarily present, however, with the usual type of cast-iron lining, and has been known to cause breakage of the lining and damage to the rams, particularly in tunnels of large diameter.

The conditions under which the shield is driven forward vary with the character of the ground. If the soil is firm it is excavated ahead of the shield, and the duty of the shield rams is mainly to overcome the frictional resistance. When the ground is soft and has a small angle of repose the shield may be used to displace part or all of the soil to be

removed to make room for the tunnel. In this case not only frictional resistance, but also the resistance to displacement has to be overcome.

When the shield is driven forward, displacing the soil, and particularly when this is done with the doors closed, the active horizontal pressures directly in front of the shield are increased to the value of the passive pressures, and at the same time rupture of the body of the soil occurs. In North River silt this increase is about 20 per cent. A proportional increase of the active upward forces will necessarily occur. If the existing condition of stable equilibrium is such that the total downward load and the frictional resistance about balance the upward forces, such an increase of the upward forces may cause the shield to have a strong tendency to "climb", and the tunnel to rise immediately after the shield has left the lining. This tendency to rise will extend only some distance behind the shield and will disappear when the abnormal active ground pressures have had time to readjust themselves. It may be relieved by admitting sufficient quantities of soil through the shield doors.

At the moment the tail of the shield leaves the lining, when the shield is pushed ahead, there exists an empty annular space around the lining. In firm soil it is probable that the first result will be that the lining will drop down to rest on the ground surface at the bottom and that the soil above the tunnel will close down until it bears against the upper half of the tunnel. Later, probably, the ground will close in at the sides. It is evident that the effect will be to introduce a bending stress in the lining, so that if the lining is not able to carry such stress the top of the tunnel will be pushed down and the sides will spread out until they bear against the soil. This tendency to distortion may be decreased, however, by filling the space with grout or other solid material.

In ground with a small angle of repose it is possible that, on account of its greater mobility, the soil may close around the tunnel immediately after the shield is pushed ahead. The construction conditions, however, will have appreciable influence on the stresses in the lining.

To begin with, the pressure of the compressed air produces bending stresses in the lining.

To illustrate this stress, diagrams have been made to show the varying conditions of stress produced by varying conditions of air pressure. Fig. 4 shows a force polygon and stress polygon under certain given conditions when the tunnel is under normal air pressure. Fig. 5 shows

the force polygon and stress polygon for the same tunnel under an air pressure of 25 lb. and Fig. 6 a force polygon and stress polygon when the air pressure balances the external pressure at the crown of the tunnel.

A comparison of these diagrams shows that while the internal stresses in the lining decrease as the air pressure increases, the eccentricity of the stress increases with increased air pressure. In cast-iron lining of the usual type, the bending moment introduced by the air

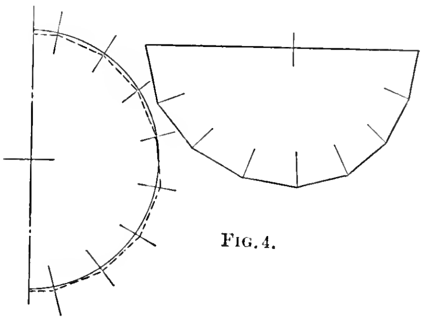


FIG. 4.

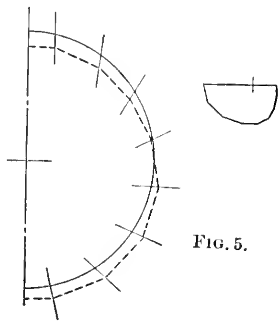


FIG. 5.

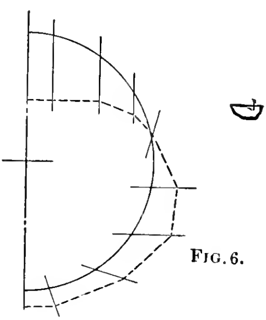


FIG. 6.

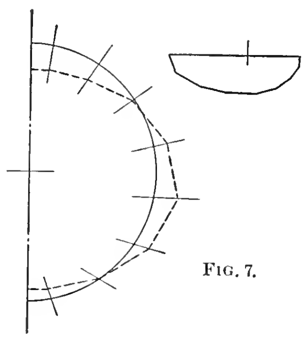


FIG. 7.

pressure may cause a tensile stress of several thousand pounds per square inch. As the cast-iron lining is not a continuous elastic structure, the effect of these bending stresses will be to open the joints between the segments. An inspection of the diagrams will show that the tendency will be to open the joints at the bottom of the tunnel on the inside and at the top of the tunnel on the outside. However, as the soil at the top may resist the tendency of upward displacement the probable net result will be a shortening of the vertical and a corresponding lengthening of the horizontal diameter.

As already stated, the pushing of the shield ahead without taking in the displaced soil increases the earth pressures in the vicinity of the shield. Similar results may be caused by pushing forward the shield in an adjacent tunnel, if that tunnel is sufficiently close. Fig. 7 shows the stress curve under these conditions. The tendency to distortion in this case is to increase the vertical and to decrease the horizontal diameter.

Stating them in the proper order, the tendencies to distortion (and if the lining is not able to withstand the stress, the actual distortions) will be, in soil with a small angle of repose, as follows: First, immediately after leaving the shield, the lining will, if the conditions are present, rise and at the same time increase the length of its vertical diameter and decrease that of the horizontal diameter. Soon after, when the soil conditions have become normal, the tendency will be to push in the lower half of the lining, thereby shortening the vertical diameter and lengthening the horizontal diameter. This tendency becomes more aggravated with an increase of air pressure. Finally when the air pressure is removed, the tendency to distortion to a great extent disappears, but at the same time the magnitude of the direct stress is increased.

The conclusions here arrived at correspond closely to the actual behavior of the tunnels driven through North River silt. The excessive rise of the Pennsylvania North River Tunnel mentioned above, which caused the work to be stopped for a period of time, happened when both the tunnels were being driven close to one another and with the doors closed. The rise was effectively checked by driving one shield well in advance of the other and by taking a sufficiently large quantity of the displaced soil into the tunnel through the shield doors; in fact it was found that the path of the shield could be adjusted readily by gauging the volume of the soil taken into the tunnel. The volume naturally depends upon a number of conditions, including the diameter of the tunnel; if that is small enough, it may be possible to push the shield ahead with the doors closed without producing a rise of the tunnel; in fact, this was frequently the experience in the tunnels of the Hudson and Manhattan Railroad under the North River which, in addition, were so far apart that the adjacent shields had little or no effect upon each other.

The flattening tendency indicated by the theoretical determination of stresses under air pressure, was a common experience in all tunnels

driven through the North River silt. In all cases, the ring of the lining was originally built true to shape. If after erection it began immediately to increase its vertical diameter, this change of shape stopped within about two weeks; thereafter the lining commenced to increase its horizontal diameter and continued to do so until the secondary lining was placed. If no initial shortening of the horizontal diameter occurred, the lining began, soon after erection, to flatten and this often continued until checked by internal bracing.

The conclusions that are to be drawn from these conditions are that for safety and economy, it may be advisable to design the lining so as to be able to carry not only the permanent stresses, but also the construction stresses, which include bending, even though the permanent forces produce compressive stresses only, and that consequently the primary lining should be the entire carrying member.

5.—North River Silt.

In the foregoing discussion, references have been made to soils with a small angle of repose, and it may be pertinent, therefore, to state some of the characteristics of the North River silt underlying the North River and adjacent waters, which is an example of a soil with a small angle of repose.

During the period of construction of the tunnels under the North River for the Pennsylvania Railroad and the Hudson and Manhattan Railroad, a great number of tests, experiments and analyses were made to determine the characteristics of the silt. As a number of tunnels already have been built in this material and more will be built, the most important results obtained will be stated here.

The weight of the silt increases with the depth below the river bed, at least to the depth that tests were made, which was to the bottom of the tunnels. At a depth of 15 ft. below the river bed, the silt weighs about 104 lb. per cu. ft.; at a depth of 38 ft. it weighs about 110 lb. and the average weight of the silt surrounding the tunnels is 108 lb. per cu. ft. The silt surrounding the tunnels contains 55% of water by volume.

The unit weight of the silt and its water content vary with the tide. At high tide the weight is greater than at low tide and the water content is less. This points to the probability that the solid particles of the silt come closer together at high than at low tide, and this is also evidenced by the fact that there is a reversing tidal motion of the silt, which rises as the tide falls and falls as the tide rises. This tidal rise and fall

amounts to an average of about $\frac{1}{8}$ in. at the level of the tunnels. It is to be presumed that it varies from zero at the bottom of the silt to a maximum at the top.

A body embedded in the silt will move up and down with the silt, but if it is in stable equilibrium will not move in relation to the silt.

The angle of repose of the silt surrounding the tunnels was determined to be less than 3 degrees. This was done by analyzing many hundred observations of the external pressures on the tunnel lining, obtained by means of specially constructed and highly sensitive pressure gauges inserted in holes in the skin of the cast-iron lining.

The fact that a shield with its doors completely closed can be forced bodily through the silt without taking a shovelful of muck into the tunnel and without requiring undue jack pressures to be developed shows that this particular soil is essentially a viscous fluid. Such a thing could not be done in clay or sand or in a mixture of such. Observations on the jack pressures used to start an actual shield in movement through the silt confirm, when analyzed, the fact that the material has an angle of repose of less than 3 degrees.

Another striking indication of the quasi-fluid nature of the silt is afforded by its vertical fluctuation due to the tidal rise and fall of the water in the North River above it. The ordinary range of tide here is only 4 or 4½ ft. and yet, at the elevation at which the tunnels lie, this small tidal range produces a change of elevation in the silt of about $\frac{1}{8}$ in. Under a tidal range of 10 ft. a change of $\frac{1}{4}$ in. in the elevation of the silt, or rather in that of the tunnel embedded in the silt, has been observed.

Certain other characteristics of the silt, observed during the construction of tunnels through this soil, should also be noted. When subjected to air pressure, the silt has the nature of a stiff clay and its consistency may readily be varied by changing the air pressure, that is to say, when the air pressure nearly balances the soil pressure, the material becomes quite stiff, but as the air pressure is reduced the silt becomes softer and softer.

6.—Ruling Requirements for the Erection and Design of Tunnel Lining.

It is evident from the previous discussion that, if the tunnel lining is designed in such a manner that it is able to carry the stresses to which it may be subjected, both during the period of construction and there-

after, and if the work of construction is carried out properly and with due regard to the peculiarities of the soil through which the tunnel is driven, the usual difficulties and expense experienced in keeping the tunnel true to line, grade and shape will be avoided.

The remedies for the rising or sinking of the tunnel are apparent, providing the tunnel is in stable equilibrium, and this is naturally a primary necessity. When the tunnel rises, it is probably due to the existence of excessive external pressures caused either by an adjacent tunnel shield or by the displacement of the soil by the shield of the tunnel itself.

The prevention of rising is to make such an adjustment of the amount of material brought in through the shield doors that these excessive external pressures are not brought into existence. When the tunnel sinks it is plainly due to leakage of water and soil through the joints of the lining over the lower portion of the periphery. The prevention consists in making the lining water and mud tight at the time of its initial erection, or as soon after as possible.

The prevention of deformation lies entirely in the design. If the lining is so designed that it is able to carry the stresses that may be brought upon it, both during and after the construction period, no deformation will occur. It is, therefore, of importance that the lining should be designed with due regard to this requirement.

When the art of building cast-iron lined subaqueous tunnels was in its infancy the size of the tunnels was kept within small limits and the tunnels were built through ground that was favorable for safe construction.

As time went on, and there developed the necessity for tunnels of larger size and in fixed locations regardless of the suitability of the soil and depth of waterway encountered, fresh problems were presented to the tunnel engineer, which indicated that either the design or the material of the lining, or both, had outgrown their original usefulness from the standpoint of safety as well as of economy. In what follows, therefore, the design of tunnel linings will be discussed while keeping in mind the safety and the economy of the design under varying conditions, both of size and surrounding material.

7.—Design of Tunnel Lining.

In undertaking the design of a tunnel lining for any given purpose and under any given conditions, the following points have to be kept

in mind: The shape, the strength, the material of construction, the water-proofing, the time required for construction, and the cost of maintenance and operation.

As regards the shape, if the cross-section of the tunnel is such that the lining is subject to direct compressive stresses only or, if that is not obtainable, to the least possible bending stresses, the least quantity of construction material will be required per unit length of the periphery. As stated in the section on determination of stresses, this points to the use of an elliptical cross-section, at least when the angle of repose of the soil is small. When it is possible to arrange the internal clearance profile in an elliptical cross-section so that no space is wasted, a further economy is obtained by having decreased the vertical diameter, because both the stresses in the lining and the difficulties of construction are thereby decreased. The possibilities of making the shape elliptical have to be studied in each specific case, and therefore no detailed comparisons, as regard economy, between circular and elliptical tunnels can be attempted in this paper.

In most cases it is necessary or advisable to maintain the proper lines and grades, either to permit the passage of the traffic for which the tunnel is intended or for the sake of appearance. Therefore some additional clearance, say from 3 to 6 in. all around the inner periphery, should be provided for the adjustment of the unavoidable deviations from the proper lines and grades that will occur during the driving of the tunnel.

As regards the strength of the lining, it has been shown that, under certain conditions, the lining is subject to bending stresses. For the purpose of avoiding non-elastic deformation, the lining should be able to carry such stresses. The ability of various lining materials to do this will be discussed in the following section. However, it may be repeated here that on account of the fact that the bending stresses occur during the construction period, as well as after, the lining placed at the time of construction should be strong enough to carry all stresses without any secondary lining placed at any later date.

The economy of construction depends not only on the unit cost of the material or materials of which the lining is constructed, but also on the quantity of material required. This includes not only the cost of procuring the materials, but also their cost of erection. It will be remembered that, if the tunnel is driven under air pressure, the cost of

labor under these conditions is exceptionally high, and that, therefore, such materials should be selected, and so arranged, as to require as little labor under compressed air as possible.

In this connection, it may be noted that while the internal diameter of the tunnel is determined by the use for which the tunnel is intended, the external and consequently the amount of excavation is in addition determined by the thickness of the lining. Therefore, in comparing various types of lining from the point of economy, the quantity of excavation should also be considered.

A further matter of economy is that of the period of time required to finish the tunnel ready for operation. Generally it is desired to complete the construction as soon as possible, because the tunnel is imperatively needed. The loss of money by reason of the tunnel not being ready for operation often cannot be estimated definitely but is, nevertheless, an important item. In addition, the monthly overhead expenses continue about the same during the whole period of construction, and the interest on the capital invested increases with the time of construction. This indicates as advisable an investigation of the relative periods of time needed to construct tunnels of various sizes, shapes and materials.

A preliminary study of the rates of progress attained in the different New York river tunnels showed that, generally speaking, the larger the tunnel the less progress, measured in linear feet of tunnel driven per month, was attained under any given set of conditions.

When the weight of cast-iron lining corresponding to the linear feet of tunnel driven per month was computed it was found that there was a fairly constant weight of cast-iron lining erected per month under any given set of ground conditions, irrespective of the size of the tunnel. This is shown in Table 1.

TABLE 1.—WEIGHT OF CAST-IRON LINING ERECTED PER MONTH IN COMPRESSED AIR TUNNELS AT NEW YORK CITY.

Material.	Weight of Cast-Iron Lining Erected per Month, in Tons.			
	P. R. R., North River.	H. & M. R. R., North River.	Dual Subway, East River.	Average.
Sand, gravel, etc.....	660	......	484	550
Mixed ground........	300	300	182	250
Rock	235	220	243	230
Silt	1 650	1 800	1 665	1 750

The cast-iron lining of the tunnels built in the neighborhood of New York City weighs, in pounds per linear foot of tunnel, about twenty-two times the square of the outside diameter expressed in feet. Consequently, the fact that the weight of iron lining erected per month under any given conditions of ground is more or less constant makes it possible to foretell the approximate monthly progress which a tunnel of any given diameter will make under any given conditions of ground. This estimate has been plotted to show the result in graphical form (Fig. 8), and it is interesting to see that the line of progress starts at zero for zero diameter rises rapidly to a maximum for a tunnel of about 10 ft. in diameter, and then diminishes as the diameter of the tunnel is increased.

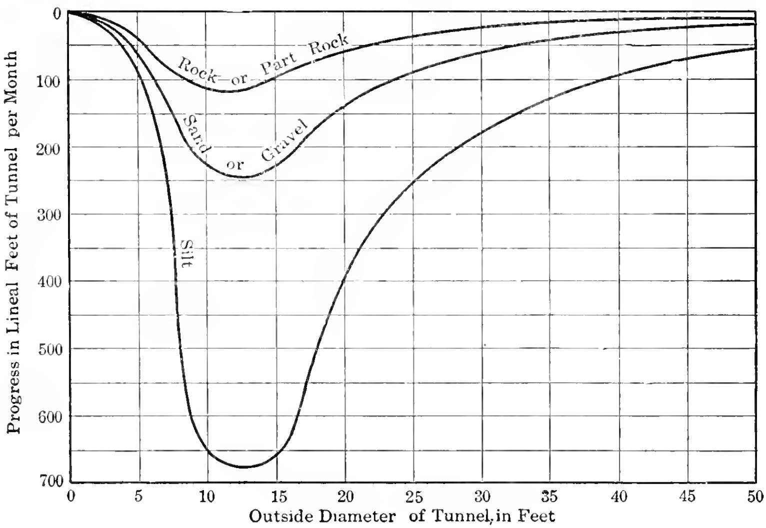


FIG. 8.

It may be said, therefore, that for shield-driven tunnels lined with cast iron of the usual type (and probably for shield-driven tunnels lined with any kind of material) the smaller the diameter, down to about 10 ft., the quicker progress will be made, the less the overhead and the interest charges during construction will be, and the sooner the tunnel will be ready for operation. This means that it is economically sound (provided that the purpose for which the tunnel is intended is not impaired thereby) to build a number of small tunnels instead of one large one. For example, it is thoroughly sound to provide a two-line railway tunnel by building two single-line tunnels rather than one

double-line tunnel, provided the quantity of material and work for the two single tunnels does not become so large in comparison with those items for the double-line tunnel that the advantage gained in the shorter construction period is counterbalanced.

The same reasoning applies to sewer tunnels, water supply tunnels and in fact to all cases where the traffic may be subdivided. A further incidental advantage is hereby gained, in that with a plurality of tunnels one or more may be shut down for repairs at times of slack traffic without shutting off the entire traffic. A constructional advantage gained by use of several small tunnels in place of one large one is that the difference in pressure between the top and bottom of the tunnel is less.

Most tunnels which have to be driven under navigable waters are limited as to the depth below the water surface at which they may be placed. For example, public authority may require that no encroachment may be made on a water depth of 40 ft. This fixes the elevation of the crown of the tunnel and this in turn fixes the position of the roadway or track which is placed within the tunnel. The smaller the vertical diameter of the tunnel the nearer to the surface this roadway or track may be kept and thus not only are the approaches made shorter or the gradients easier, and the total length of the tunnel decreased, but the vertical height through which every person or vehicle which uses the tunnel has first to be lowered and then to be raised is diminished. Thus a saving in energy is introduced and this saving is continuous throughout the entire life of the structure. If capitalized, this saving may amount to an appreciable sum of money.

8.—Materials of Construction.

Brickwork and Concrete.—Most of the usual materials of construction have been adopted for tunnel linings, and may be used if they suit the existing conditions. A tunnel driven through non-waterbearing rock may not need any lining at all, or perhaps only a facing of concrete to improve the appearance and to protect the rock against weathering. A tunnel constructed in dry soft soil may be lined with brick or concrete, providing that no shield-ram pressures have to be supported on the lining and that no soil pressures are likely to occur until the mortar or concrete has set. This indicates the use of brickwork or concrete,

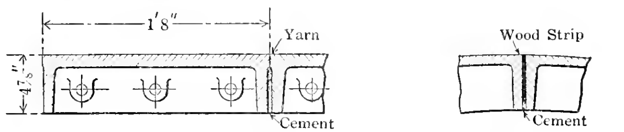
particularly as a secondary lining. The primary lining may be either a temporary timber construction or a permanent lining of timber, concrete blocks or metal. In the first case the masonry lining should be able to carry the full external loads; in the second case the masonry lining is used either to carry part of the stresses or to provide a smooth interior for the tunnel or to protect the primary lining. The use of precast concrete blocks placed without mortar will be discussed later.

Wood.—On account of its lack of durability, the use of wood is generally limited to temporary lining, but for this purpose it is quite common, from the timbering of a heading to the lining of full-size tunnels. For water-carrying tunnels in water-bearing soils, however, wood may be a suitable material. A special case where wood is indicated as a proper material for tunnel lining, is that of discharge tunnels of power houses, as it has been the experience that concrete or mortar disintegrates under the action of the discharge water. A wooden tunnel lining may be either arch shaped and made of short lengths of timber with circumferential butt joints, or it may be made rectangular, subjecting the timber to bending stresses. On account of the softness of this material, an internal wearing surface should be provided, either of masonry or of renewable planks.

Cast Iron.—Under proper conditions, cast iron is a material eminently suitable for use as tunnel lining on account of its rugged, durable character and its ability to carry compressive stresses.

The tunnel shield, and incidentally the cast-iron lining of the type generally used, was originally invented by Marc Isambard Brunel and patented by him in 1818, but the segmental iron lining was not adopted until 1869 when it was used for the Tower footway tunnel, with an outside diameter of 7 ft. 1¾ in., at London under the Thames River. The lining is made up of segments, bolted together, forming a ring, and the adjacent rings are also bolted together. Fig. 9 shows sections of the cast-iron lining used for the Central London Railway in London clay, which is a stiff non-waterbearing clay. The outside diameter of this tunnel is 12 ft. 6 in. and no secondary lining is used. Fig. 10 shows sections of the cast-iron lining used for the greater part of the Pennsylvania Railroad Tunnels in the silt under the North River at New York City. The outside diameter of this lining is 23 ft. and a secondary lining of concrete was used, making the total thickness of the tunnel lining 2 ft.

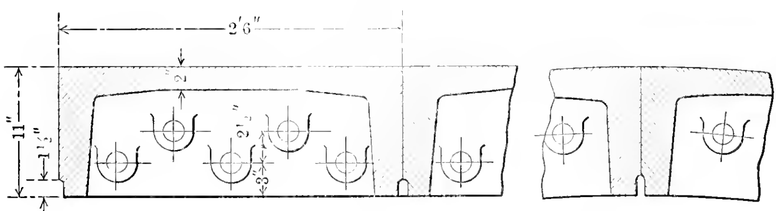
It will be noticed that the method of making the joints is different in the two tunnels shown. In the Central London Tunnel the surfaces of the flanges were not machined. The radial joints were made by packing a creosoted wood strip between the adjacent flanges and bolting them together. For the circumferential joints, on account of the necessity of sustaining the shield-ram pressure, the flanges were brought into contact, metal to metal, along the skin and a packing of yarn was placed at the bottom of the joint behind the bolts. The remainder of the joint was filled with mortar except where water was met, and here the usual mixture of sal-ammoniac and iron borings was packed into the joint. The radial joints were also finished with a pointing of cement or of rust caulking, as required.



RADIAL JOINT CIRCUMFERENTIAL JOINT

DETAILS OF CAST IRON LINING FOR CENTRAL LONDON RAILWAY TUNNELS

Fig. 9.



RADIAL JOINT CIRCUMFERENTIAL JOINT

DETAILS OF CAST IRON LINING FOR PENNSYLVANIA RAILROAD NORTH RIVER TUNNELS

Fig. 10.

In the Pennsylvania Railroad Tunnels all flange surfaces were machined so as to ensure an exact bearing surface over the entire depth of the flange. A caulking groove about 1½ in. deep, however, was provided along the inside edge of the flanges. This groove was used to make the joint water-proof by filling it with rust caulking, and the bolts were water-proofed by packing grummets consisting of rings of yarn dipped in red lead under the heads and nuts of the bolts.

The main advantages of cast-iron lining are that it may be handled roughly without being damaged; that it may be procured in the shape

desired and in units of a size limited only by the facilities for casting and the weight that can be handled in the tunnel; that it may be erected and connected in a reasonable time, and that it may be made almost water-tight by caulking the joints and grummeting the bolts. The accuracy with which the faces of the flanges may be machined is nearly absolute and it is possible to erect iron thus machined to perfect shape. The efficacy of the lining, as a structure and as a water-proof envelope, then depends on its capability of resisting, without deformation, the stresses which come upon it.

Cast-iron lining of the type described forms an efficient structure in soils with a large angle of repose, if the diameter of the tunnel is not too large. The question of cost is not considered for the present.

The objections to cast-iron lining are as follows: The structure, in effect, is not capable of resisting stresses other than compressive. This is not so much due to the cast iron itself, which might be relied upon to carry a reasonable tensile stress, but to the method of fastening the segments together, which permits them to separate slightly under a bending stress. The result is that during construction in soil with a small angle of repose it is subject to various non-elastic deformations, and further the pressure of the compressed air causes, as has been stated before, bending stresses in the lining, producing distortion.

In soils of the character of the North River silt, deformations may occur due to temporary disturbance of the earth pressures on account of the pushing forward of the shield, particularly if the shield is driven ahead without taking in the full volume displaced. When such distortions occur, it is necessary to provide temporary bracing and support until the supplementary inside lining is in place, and this is expensive both in time and money.

In soil of moderately high angles of repose, immediately after the shield leaves the lining, this is surrounded with an annular space only partly filled with solid matter. This condition produces local pressures on the lining, causing it to deform; then again, when the air pressure is removed the conditions of equilibrium are changed and the lining is subject to further deformation.

The non-elastic deformation has another serious effect on the structure. The horizontal joints between the cast-iron segments, which are generally machined and expected to bear on the whole surface of

the flange, open up either on the inside or on the outside and thus not only is the strength of the ring as an arch greatly decreased but also the efficacy of the caulking is diminished. This is particularly important, because the caulking, in order to be effective, must be done under air pressure, and when the pressure is removed, deformation takes place, opening the joints and destroying the water-tightness. In a material such as North River silt, having tidal movements, an additional and periodical working of the joints may occur which will make the caulking ineffective, particularly in tunnels with no inside concrete lining. Leakage necessitates continuous expenditure for pumping, and in a material like North River silt, even a minute leakage produces a settlement of the tunnel, affecting its gradient.

The skin of the cast-iron lining has to support the thrust of the shield rams. On account of the construction space needed for the rams, their pitch-circle must be several inches inside of the skin-circle. This causes bending stresses in the rams and in the lining and, in large tunnels, results in bending and jamming of the rams, and breakage of the lining.

These considerations suggest the following changes in the design of cast-iron lining. The depth of the circumferential flanges should be made large enough to insure compressive stresses only in the lining or at least tensional stresses no greater than can be carried safely by the cast iron and the connection between the cast-iron segments.

The sections forming a ring should be connected so that non-elastic deformations cannot occur, and longitudinal ribs should be provided to support the thrust of the shield rams.

By constructing stress polygons for tunnels of various diameters it has been found that, if the pressure at the top of the tunnel is 4 000 lb. per sq. ft., the weight of the soil 120 lb. per cu. ft., and the angle of repose is 2° 52′, the maximum eccentricity e of the circumferential force in the lining, when the outside diameter lies between 12 ft. and 36 ft., may be expressed empirically by

$$e = \frac{d^2 \sqrt{d}}{480} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

where d is the outside diameter in feet and e is expressed in inches.

It is desired to make clear that the soil characteristics and weights of lining from which this formula is derived have been deliberately

chosen to accentuate the effect of a heavy soil together with a low angle of repose. The flanges and thicknesses of lining given in the following pages, therefore, are exaggerated. In soil of the character of North River silt, for example, the eccentricity will be found to be considerably less.

If the depth of the flange is made equal to $4e$, the tensile stress will not be greater than may be brought safely upon the cast iron, and the connections between the segments of the lining may be made strong enough to carry this stress. The depth of the flange will accordingly be as follows:

Outside diameter, in feet...............	12	18	24	30	36
Depth of flange, in inches..............	4	12	24	41	65

The inside diameter Δ is determined by

$$\Delta = d - 8e$$

By differentiation, the maximum value of e may be determined as 26.2 ft. In other words, in order to obtain a cast-iron lining not subject to non-elastic deformation under the conditions assumed, the inside diameter cannot be greater than 26.2 ft. Before this limit is reached, however, the size, weight and number of the segments of the lining will have become unwieldy.

It is, however, quite possible to construct tunnels with a cast-iron lining having a flange depth less than that required to make the lining self-sustaining; in fact, the primary lining may be and has been made of a thin metal plate only. When the lining is not self-sustaining, it must be temporarily supported during construction and a secondary lining must be provided. The question of which method to adopt is essentially one of economy, but it must also be kept in mind that when the primary lining is not self-sustaining, the water-proofing becomes more uncertain and expensive.

It has been found, by plotting the weight of cast-iron linings of tunnels actually constructed in soils of this character, that the weight may be expressed by the equation $W = 22d^2$ where W is the weight, in pounds per linear foot of tunnel and d is the external diameter, in feet.

Precast Concrete Blocks.—As previously stated, concrete is not, except under special conditions, a suitable lining material for a shield-

driven tunnel, except in the form of precast blocks. In this shape it is well suited for tunnels of any diameter when the soil is dry and has a large angle of repose, and it may be used in tunnels of small diameters in water-bearing soil with a small angle of repose, providing it can be made water-tight; but, according to the foregoing stress determination, in the present state of the art it is not suitable under any other conditions.

The advantages of the precast concrete blocks are that they may be made of any shape and size desired, at a reasonable cost, and that they may be handled with ordinary care without being subject to serious damage.

The disadvantages of precast concrete blocks are, as a whole, the same as those of cast-iron lining, but to a greater degree; namely, they cannot resist other than compressive stresses and the water-proofing is uncertain in its efficacy.

It has been stated previously that bending stresses occur during the construction. These stresses the concrete-block lining cannot resist, even though interlocking arrangements be provided between adjacent segments, because it would be a practical impossibility to cast the blocks so as to secure the absolute fit necessary to prevent any motion in the joint. The result is, therefore, that the tunnel will distort and the joints open, when bending occurs, thereby throwing the full load on a small bearing surface either at the inside or outside edge, and producing a grave possibility of spalling off the edges of the blocks.

Owing to their bulk, the concrete blocks would have to be rather short, particularly in tunnels of moderate or large size. Consequently the taper of the individual blocks would be slight, and it is entirely within the possibilities when the tunnel distorts and the joints open, that the block might be free to slide in under the external pressure, particularly when the outside edges are spalled off.

In order to make a tunnel lined with such blocks safe during the construction period, it would be necessary to make arrangements on the following general lines: To provide the blocks with steel rings securely fastened into them and during the time the air pressure was on to fasten tie-rods to these rings in the directions where increases of diameter might occur, and at the same time to support the lining with struts in the directions where the diameters might decrease. Such temporary support would however be expensive and interfere with

the work of construction. The stresses in the structure under normal air pressure might be taken care of by making the thickness so great that tensile stresses would not occur. As will be shown hereafter, this is only possible up to a certain inside diameter. The tensile stresses in the permanent lining might also be relieved by introducing proper permanent internal bracing of the lining, which, however, again would add to the cost of the structure.

The concrete blocks might be made reasonably water-tight by the addition of some water-proofing compound. The joints between the blocks could be water-proofed by means of water-proofing material, but in order to make such water-proofing efficient, it would have to be carried out with the greatest care at each individual joint before the next block was placed, thus retarding progress at the period of construction, when speed is of paramount importance for economy.

The efficacy of the water-proofing however would depend on the absolute prevention of distortion of the tunnel.

As stated above, Equation 10 expresses the eccentricity of the circumferential force. In order to avoid tensile stresses, the thickness of the lining must be not less than $6e$. This would require the following thickness of the lining:

Outside diameter, in feet..............	12	18	24	30	36
Thickness of lining, in inches..........	6	18	36	61	97

It would appear, therefore, that the thickness of this lining becomes so great as to be impracticable when the outside diameter of the tunnel is more than 24 ft. Furthermore, the inside diameter should not be increased beyond 20 ft., because the inside diameter, Δ, is $\Delta = d - 12e$, and by differentiation, the maximum value of Δ is determined as 20 ft. In other words, in order to obtain a concrete-block lining not subject to non-elastic deformation under the conditions assumed, the inside diameter cannot be greater than 20 ft. unless inside bracing is provided.

Structural Steel.—So far, all the usual materials of construction have been considered except structural steel, which up to the present time has been used for tunnel lining only to a very limited extent, in spite of its many apparent advantages. The most probable reason for this is that the standard material for primary lining for subaqueous tunnels, cast iron, has proved itself generally satisfactory, although in

soils having a low angle of repose it has become apparent that the limit of possible size has nearly been reached.

Steel has been used as primary lining for tunnels under the Spree and the Elbe Rivers in Germany. In both cases the steel lining was used as an envelope only, inside of which the permanent and supporting lining was constructed. Light wrought-iron plates were used for the old North River Tunnel, commenced in 1874. Steel has also been used for a short length of the intake tunnel of the Hudson and Manhattan Railroad power-house at Jersey City, N. J. In this case, the steel lining was made of 13-in. ship channels, bent to the curvature of the tunnel and provided at the ends of each section with angle flanges, producing sections of steel similar to the usual cast-iron sections. These sections were erected and bolted together, following the procedure of cast-iron lining. This tunnel was provided with an internal wearing surface of masonry.

None of these types of steel lining is self-supporting but requires a secondary carrying lining. For the purpose of investigating the possibilities of a self-sustaining steel lining, the writers have, therefore, attempted to design such a lining. Fig. 11 shows its general character. It consists essentially of circular plate girders, spaced at intervals, supporting the steel plate envelope or skin. The girders are intended to be able to carry the forces that may come upon them without non-elastic deformation, but, as they necessarily must be brought into the tunnel in sections, they must be spliced. The compressive stresses will readily be transmitted through the machined abutting faces, and the tensile stresses may be transmitted through splice plates connected to the adjacent sections by means of tight-fitting pins or tapered dowels. Fig. 12 is a photograph of a model of a section for a tunnel 18 ft. in diameter.

The advantages of such steel lining are, first, that it may readily be made strong enough to carry without non-elastic deformation the forces to which it may be subjected, and second, that it may be made absolutely water-tight by means of electric welding.

The principal criticism that might be made against the steel lining is probably that of possibility of corrosion. All the evidence, however, that so far has come to the knowledge of the writers appears to indicate that steel embedded in soil under conditions similar to those to which a tunnel lining is subjected does not corrode. More light on this matter would be desirable. Some evidence is afforded by the

shield of the North Tunnel of the up-town tunnels of the Hudson and Manhattan Railroad. The skin of this shield consisted of a cylinder made up of two thicknesses of ⅜-in. steel plate. The diameter of the cylinder was 19 ft. 11 in. and its length from cutting edge to end of tail was 10 ft. 6 in. This shield was erected in 1890 and was driven forward about 2 000 ft. in a little less than a year. It is not known whether the shield was painted or otherwise protectively coated before it started

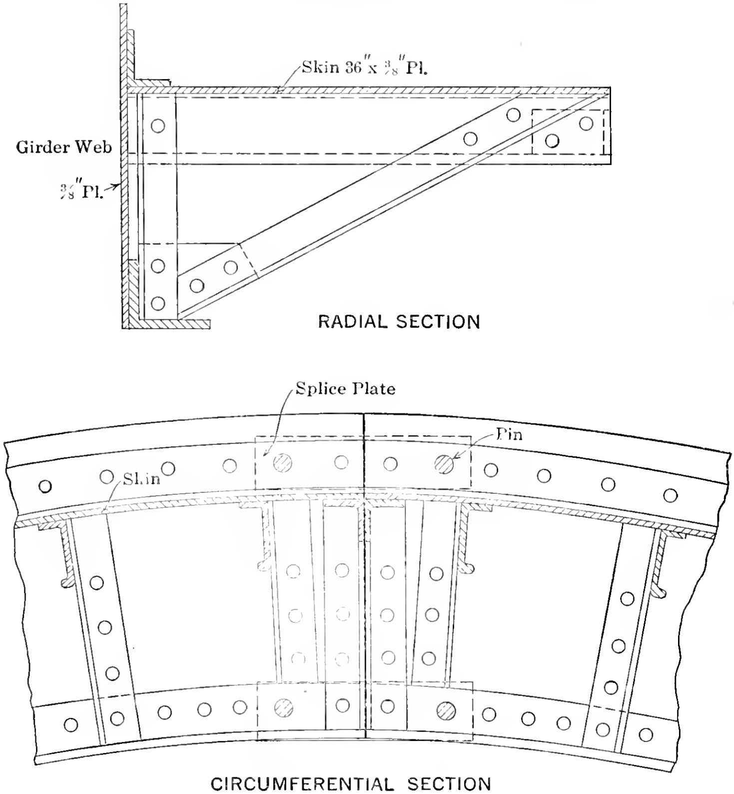


Fig. 11.

on its journey, but it is reasonably certain that any coating it may have had was rubbed off after traveling 2 000 ft. through the silt.

The work on the tunnel was abandoned in 1891, and the shield was left encased in the North River silt about half way across the river. Inside, the shield was filled with water and muck. In 1902, eleven years after the tunnel had been abandoned, it was cleaned out. The shield was found to be in good condition and, after repairs to the machinery, was used to drive the tunnel the remaining distance

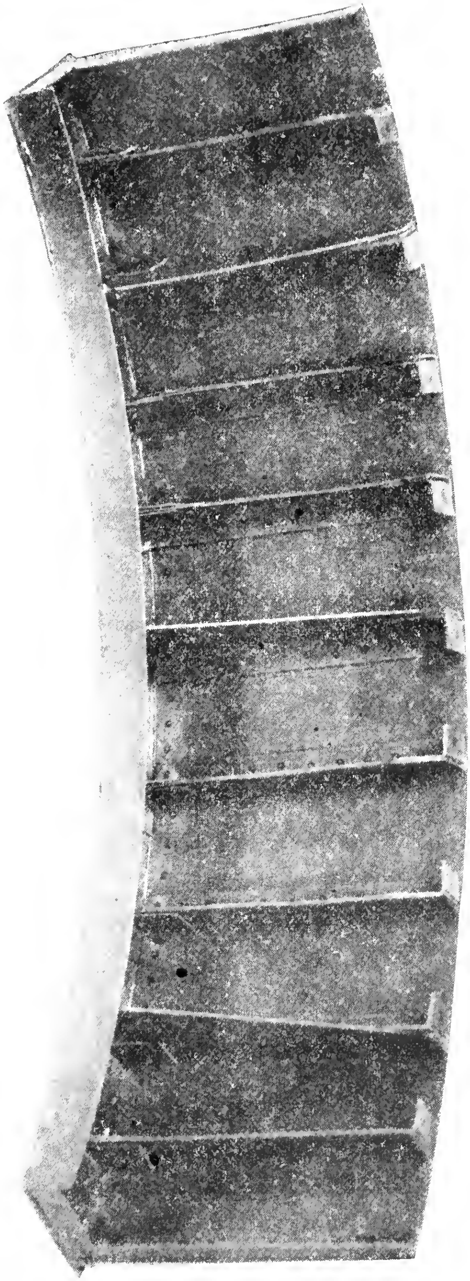


FIG. 12.—MODEL OF A STRUCTURAL STEEL SECTION FOR 18-FT. TUNNEL.

across the river where it arrived and was dismantled in 1904, except the outer shell, which was left in place, the cast-iron lining being erected inside it. In other words, a steel cylinder with an unprotected surface of about 750 sq. ft. remained embedded in North River silt for eleven years without being impaired for use.

By making designs for a lining of this type for several different sizes of tunnels under the same assumptions as to soil characteristics used previously, and by selecting the girder depth expressed in inches

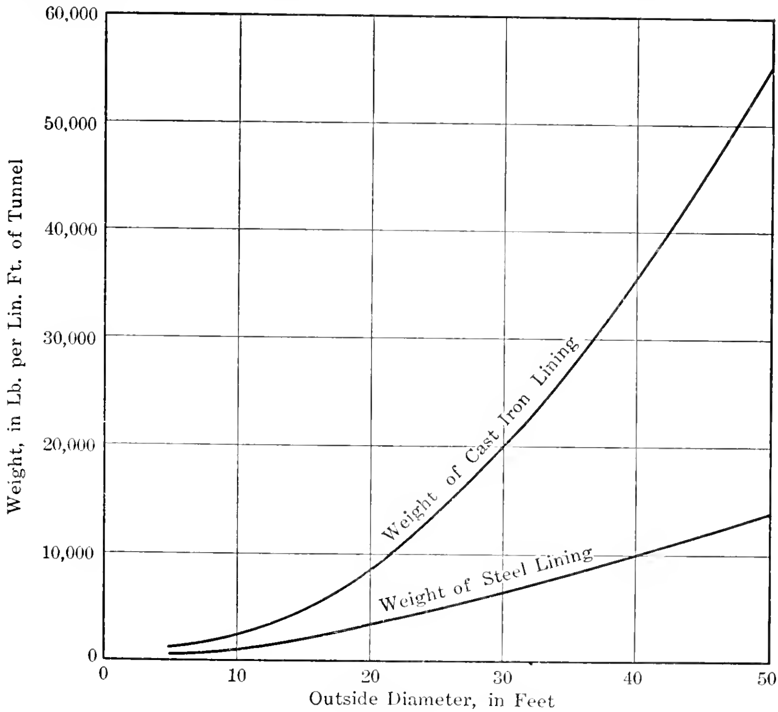


FIG. 13.

equal to the outside diameter d in feet divided by 1.2, it has been found that the weight W of the lining, in pounds per linear foot of tunnel, may be expressed by

$$W = 4\,d^2 + 90d \ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

It will be found that weights of steel lining based on this formula, when compared with weights of cast-iron lining, range from 59% in the case of a 10-ft. tunnel to 26% for a 50-ft. tunnel.

Fig. 13 shows these weights plotted for tunnels up to 50 ft. in diameter.

9.—Secondary Lining.

The purpose of the secondary lining of a tunnel may be either to act as a carrying member, to produce a smooth inner surface, to give additional weight, or to protect the primary lining from corrosion. It generally consists of either brickwork or concrete. It has been stated before that in order to avoid troublesome deformations in a tunnel driven under air pressure, the primary lining should be designed so as to be able to carry the stresses to which it is subjected during the construction, as well as the permanent stresses, without non-elastic deformation. If that is done, no secondary lining is needed on account of strength and it might, if intended for that purpose only, be dispensed with.

As to the use of a secondary lining to produce a smooth inner surface, this is necessary when the tunnel is intended to carry water if the primary lining does not provide a smooth inner surface, for example, when the primary lining is constructed of metal. If the tunnel is intended to be used as a railroad or a highway, there does not appear to be any more reason to hide the metal construction than if the structure were a bridge.

10.—Cost of Tunnel Linings.

The previous sections of this paper have discussed the merits and demerits of various materials of tunnel linings from the point of view of serviceability without reference to the matter of cost. This feature, however, is of prime importance and often is a determining factor as to whether a tunnel is to be constructed or not, or if constructed, determines its capacity.

It was attempted, therefore, to formulate certain expressions by which the probable cost per unit of length of tunnels of any given size to be constructed through various kinds of ground, could be determined, if not absolutely, at least relatively.

The prices of labor and materials, however, usually are in a state of flux, and this is particularly true at the present time. Furthermore, the probable cost of labor and materials on any specific piece of work is so tied up with the local conditions which surround and attend that work that the conclusion was reached that such generalized and sweeping formulas were more or less spurious and untrustworthy and might lead to erroneous results if applied without due caution and reserve.

It may suffice to repeat that, as far as the use of a tunnel is concerned, the internal cross-section is the measure of its capacity. As far as the stresses which will exist in the lining are concerned, the outside diameter is the ruling factor. Hence in comparing one type of tunnel lining with another for tunnels of the same internal cross-sections under the same external conditions of ground pressure, assuming that the various linings compared have been designed so that the tunnel shall have equal strength in each case, the following factors should be brought into the comparison:

1.—The volume and cost of the excavation;

2.—The weight and cost of the lining material;

3.—The probable rate of advance;

4.—The permanence of the lining material;

5.—The possibility of making the lining water-proof.

11.—Conclusions.

From the previous discussion the following conclusions are reached:

1.—When the characteristics of the soil through which a tunnel is to be built are known, it is possible to determine the stresses in the tunnel lining.

2.—In order to obtain direct compressive stresses only in the lining of a circular tunnel, the diameter of the tunnel must be limited to a certain value which varies directly as the angle of repose of the soil in which the tunnel is embedded.

3.—In soil with an angle of repose producing bending stresses in a circular tunnel, it is possible to reduce, and sometimes to eliminate, the bending stresses by making the shape of the tunnel elliptical.

4.—If the total vertical downward forces are less than or equal to the total maximum passive upward forces the tunnel will not sink.

5.—If the sum of the total downward load and the frictional resistance is greater than the total active upward force the tunnel will not rise.

6.—The pressure of the compressed air in the tunnel during construction produces bending stresses in the lining.

7.—The shoving of a shield through plastic soils without taking in the full volume displaced by the shield induces temporary

pressures in the ground which tend to deform and displace the lining.

8.—The lining should be designed so as to be able to carry not only the permanent stresses but also the construction stresses, which include bending, even though the permanent forces produce compressive stresses only.

9.—Consideration should be given, in each specific case presented, to the advantages and disadvantages, from an engineering viewpoint, of making the primary lining the entire carrying member, or of supporting the primary lining when and where necessary until the secondary lining has been placed.

10.—Up to the present, the rate of progress of a shield-driven subaqueous tunnel has been a function of the diameter of the tunnel. For each variety of ground this relationship is different, but in general the rate of advance increases rapidly from zero diameter up to a diameter of about 10 ft. and then decreases with increase of diameter.

11.—In soils with a low angle of repose, for any specific case presented, there is a limiting inside diameter (which may be determined for that case) beyond which the primary lining, whether of cast iron or of concrete blocks, cannot be designed to stand without internal bracing.

The subject covered is one on which there is still much difference of opinion and doubt. The writers hope that these notes may give rise to a discussion on the design and construction of tunnels which will help the engineer who has to deal with this most fascinating work.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE DUTY OF WATER IN THE PACIFIC NORTHWEST*

BY J. C. STEVENS,† M. AM. SOC. C. E.

SYNOPSIS.

The duty of water for any particular locality is susceptible of analytical determination if the necessary physical characteristics of topography, soil and climate, and the crops to be grown are known. The object of this paper is to strip this subject of some of the ornate generalities that usually characterize its discussion, and to suggest lines along which future research should be conducted in order to supply the missing data necessary to the solution of the problem.

The subject is first considered analytically. The process is illustrated by an actual example, and the correctness of the determination substantiated by results actually secured on projects where crop statistics and other data are available.

Briefly stated, the determination of the duty of water consists in first fixing the average percentage of soil moisture that should be maintained for the particular soil and crops, and then finding a quantity of irrigation water that, with the precipitation and the unavoidable losses, will maintain that amount of soil moisture.

This method makes the free soil moisture in the root zone of the plants the index of plant sufficiency. It is hoped the suggestion will lead to additional research to determine the amount of free soil moisture

* This paper will not be presented for discussion at any meeting of the Society, but written communications on the subject are invited for subsequent publication in *Proceedings*, and with the paper in *Transactions*.

† Portland, Ore.

in various types of soils and for various crops that will give the highest efficiency in agricultural practice. Some work along this line has already been done and the results of such investigations have been used in making up the various formulas and criteria presented in this paper.

Terms Used.

The net duty of water is taken to mean the amount of water artificially delivered to the margin of the farms for irrigation. It will be expressed in depth on the land in feet or inches, which is identical with acre-feet or acre-inches per acre.

Precipitation includes rain, snow, hail, sleet, dew and frost.

Irrigation water is the water artificially delivered to the land. It does not include precipitation.

Evaporation is the return of surface water to the atmosphere. It is considered in three phases—evaporation of precipitation, of irrigation water, and from soil storage.

Percolation is the passing of water in the soil beyond the reach of plant roots.

Surface waste is the surface run-off from irrigation water or precipitation.

Soil storage is the water held in the soil by capillary forces within the root zone of plants.

Water-table is the point of soil saturation by gravity water.

Hygroscopic moisture is the amount of water an artificially heated soil will absorb from moist air upon cooling. It is not available for plant growth.

Capillary water is the water held in the interstices of the soil against gravity.

Gravity water is all water in the soil not hygroscopic or capillary. It will flow off by gravity in drains.

Plant consumption is the water taken by plant roots.

Free moisture is any soil water available for plant growth.

What Constitutes the Net Duty of Water.

The net duty of water is very simply conceived in two parts:

1.—The quantity of water actually consumed by plants; and,

2.—The losses incident to supplying that quantity to the plant roots.

The losses are of three kinds:

1.—Evaporation,
2.—Percolation,
3.—Surface Waste.

Of these losses, percolation and surface waste are entirely under the control of the irrigator, while evaporation is partially under control. It is only necessary, therefore, to consider to what extent these losses, in the exercise of good husbandry, are necessary and unavoidable and thus may be considered a beneficial use of water.

Plant Consumption.—Every plant requires certain ideal conditions for optimum growth. These conditions involve a minimum water consumption. Any material departure from these ideal conditions is reflected in an increased water consumption. In other words, Nature tries to remedy any deficit of plant food, or energy, by an increase in transpiration.

It has been found that the water consumption of plants is influenced by environmental factors as follows:

1.—The addition of fertilizer to a fertile soil has no effect on plant consumption, but materially reduces the water consumption if added to an infertile soil.

2.—Soil moisture is without effect provided there is sufficient for plant growth.

3.—Radiation, *i e.,* intensity of sunlight, increases transpiration in almost direct proportion.

4.—Transpiration varies almost directly with the saturation deficit (*i. e.*, 1 — relative humidity).

5.—Cool weather plants such as wheat, barley, rye, oats, etc., use a minimum of water in cool weather and a maximum in warm weather.

6.—Warm weather plants such as corn, millet, rice, sorghums, etc., use a minimum of water in warm weather and a maximum in cool weather.

7.—Wind movement increases plant consumption.

8.—A lack of carbon dioxide, the presence of parasites, frequent cropping or any other deleterious influence will increase the water consumption.

By far the most extensive experiments on the water consumption of plants are those of Messrs. Briggs and Shantz* at Akron, Colo., 1911-15.

* *Journal of Agricultural Research*, Vol. 3, No. 1, and *Bulletin 285*, Bureau of Plant Industry, U. S. Department of Agriculture.

The method followed was to grow plants in suitable pots, with their surfaces sealed by wax. A record of the amount of water supplied during growth was kept. At maturity the plants were removed and kiln-dried. The consumption is expressed in pounds of water per pound of dry matter or grain produced. Table 1 gives a summary of the results thus secured.

TABLE 1.—PLANT CONSUMPTION IN POUNDS OF WATER PER POUND OF KILN-DRIED MATTER AND OF GRAIN OBTAINED AT AKRON, COLO., 1911-12-13.

Crop (Mean of Genus).		Pounds of water per pound of Grain.	Pounds of water per pound of Whole plant.
Grains	Proso	454	293
	Millet	483	310
	Sorghum	767	322
	Corn	1 250	368
	Wheat	1 350	513
	Barley	1 400	534
	Oats	1 600	597
	Rye	2 000	685
Hay	Sweet Clover	......	770
	Vetch	......	794
	Red and Crimson Clover	......	797
	Alfalfa, four varieties	......	831
	Wheat and Brome Grass	......	861
Tubers	Sugar Beets	......	397
	Potatoes	......	636
Weeds	Tumble Weed	......	287
	Purslane	......	292
	Buffalo Grass	......	308
	Russian Thistle	......	336
	Mountain Sage	......	616
	Sunflower	......	683
	Western Ragweed	......	948

In applying the results obtained at Akron to any particular locality, a comparison of climatic conditions will indicate whether or not additions or reductions should be made. For forage crops, the consumption ratio must be reduced to terms of cured hay, instead of dry matter. Ordinarily about 70% of the consumption for dry matter can be used with safety.

Making this reduction, for alfalfa and clover the water consumption is 0.42 ft. in depth per ton of cured hay produced. For the grains, wheat will require 0.03 ft.; oats, 0.02 ft.; rye, 0.04 ft., and barley and corn, 0.025 ft. in depth per bushel of yield.

With these data, it is possible to determine for any particular locality, crop classification and yields, the approximate amount of water that will be required for plant growth.

The monthly rate at which water is consumed may be taken as approximately proportional to the monthly increment to temperature during the period of growth. Thus, assuming that growth begins April 1st, the total plant consumption may be distributed in proportion to the increase of monthly temperature over that of March.

Evaporation.—Having determined the amount of water consumed in plant growth, it is necessary to determine the losses incident to supplying that quantity to the plants. The three sources of loss, viz., evaporation, percolation and surface waste, will be considered in order.

As previously stated, evaporation is under the partial control of the irrigator. A great saving can be made by irrigating in deep furrows, by cultivation and maintaining a mulch on the surface. For alfalfa hay, the water should be applied just before cutting in order to start the second crop. The old plants shade the ground and diminish the effect of wind, thus greatly reducing evaporation.

Evaporation is considered in three phases according to the origin of the water evaporated:

1.—From precipitation.

2.—From irrigation water at the time of application.

3.—From soil storage, *i. e.*, water raised by capillary action to the surface and then evaporated.

The amount of precipitation evaporated can only be fixed arbitrarily. Light summer showers may all be lost, and of heavier rains from 20 to 75% is likely to be dissipated. In duty-of-water calculations it is only practicable to consider the normal monthly precipitation. The following formula will give approximate results for temperatures above freezing:

$$E_r = \frac{T}{100} \sqrt{R} \qquad (1)$$

Where E_r = Evaporation from precipitation, in inches per month;
T = Mean monthly temperature, in degrees Fahrenheit;
R = Monthly precipitation, in inches.

The amount of irrigation water evaporated immediately following its application will depend on the condition of the soil, nature of crops and method of its application. When water is first applied the rate of evaporation is high, but the quantity available for evaporation rapidly diminishes as the water soaks into the soil. Once in the soil, it can

only be evaporated by being raised to the surface by capillarity when the surface becomes drier than the soil below. Experiments show that 10% of the amount applied is a conservative figure for gently rolling or level lands. For steeper lands, from 15 to 25% may be allowed. Losses in excess of these quantities are readily prevented and cannot be considered a beneficial use of water.

Evaporation from soil storage constitutes the most important source of loss. It has been found that there is a fairly definite relation between the amount of evaporation, the moisture content, and temperature of the top soil layer. This relation is practically independent of the nature of the soil.

When the water-table is within the zone of capillary rise, there is a certain moisture content in the top layer which depends upon the height of capillary rise for that particular soil, and the position of the water-table. For a soil of uniform texture, the free moisture content may, for practical purposes, be considered to vary uniformly from saturation at the water-table to zero at the limit of capillary rise. For example, consider a soil with 40% voids and of such fineness that the limit of capillary rise is 5 ft. If the water-table is 5 ft. below the surface, the free moisture content at the surface will be zero and there will be no evaporation. If the water-table should rise to 4 ft., the free moisture content of the top layer becomes one-fifth that at saturation, or 8% by volume, and evaporation soon begins.

The soil properties required for the determination of evaporation are the percentage of voids and the limit of capillary rise. The latter will vary somewhat with temperature but will be found to have values varying from a few inches in coarse sands to 10 ft. or more in fine silts and clays. It can be determined by packing soils in long glass tubes closed at the bottom with muslin. The bottoms are then set in a shallow tank of water and the height to which the water rises is observed. It may require several months to determine this limit in the finer soils.

The results secured by Charles H. Lee,* M. Am. Soc. C. E., in Owens Valley, California, constitute the only data on soil evaporation extending over an entire year. His results also include the transpiration of salt grass. The loss was measured from buried tanks in which the water-table was maintained at various levels. In Table 2 is given a summary of his results.

* *Water Supply Paper No. 294*, U. S. Geological Survey.

TABLE 2.—OWENS VALLEY SOIL EVAPORATION.

Period.	Average air temperature, Owens Valley.	EVAPORATION PER MONTH, IN INCHES, FROM TANK NO.:						
		1	2	3	4	5	6	7
		Average depth to ground-water, in inches.						
		15	59	54	47	35	23	16
1910								
June	73	3.2	0.2	1.9	1.8	1.6	4.2	5.3
July	78	3.6	0.9	3.7	4.1	4.2	5.6	5.7
August	77	4.3	2.1	4.6	5.2	6.7	8.0	7.3
September	70	4.4	1.5	3.8	3.5	5.3	8.4	5.7
October	59	3.7	0.9	2.3	2.3	3.5	3.9	4.0
November	48	2.6	0.4	0.9	1.2	1.4	1.5	2.1
December	42	2.4	0.2	0.6	0.6	0.6	0.4	1.0
1911								
January	42	2.5	0.2	0.4	0.3	0.4	0.3	0.6
February	37	3.2	0.1	0.5	0.1	0.2	0.4	0.7
March	50	3.1	0.1	0.5	0.1	0.2	0.7	1.5
April	54	3.3	0.3	1.1	1.1	1.7	3.2	3.7
May	59	3.6	1.1	2.2	3.0	4.7	6.0	5.6
The year	57.4	39.9	8.0	22.5	23.3	30.5	42.6	43.2

In the absence of more complete information, the following formula for soil evaporation is presented. The only claim for it is that it approximately fits the results of Lee's experiments in Owens Valley.

$$E_g = 0.18 \left(1 - \frac{d}{H}\right)(T - 32)\,K \quad \ldots\ldots\ldots\ldots (2)$$

in which

E_g = Evaporation from soil, in inches per month;
d = Depth to the water-table;
H = Height of capillary rise;
T = Mean monthly temperature;
K = Factor having a value of unity for the Owens Valley experiments.

The results obtained by R. B. Sleight,* Jun. Am. Soc. C. E., at the Denver laboratories indicate that the above formula would be approximately applicable to them if the results covered an entire year. Individual months are likely to be in error where air temperatures are used, but in the entire year such errors are compensating.

* "Evaporation from the Surfaces of Water and River-bed Materials", *Journal of Agricultural Research,* July 30th, 1917.

The following shows the agreement between the evaporation by the formula and that measured in Owens Valley for the year from June, 1910, to May, 1911, inclusive:

Tank No.	Observed.	By Formula.	Percentage of Error.
1	39.9	46.1	+ 14
2	8.0	17.3	+ 116
3	22.5	20.3	— 10
4	23.3	25.0	+ 7
5	30.5	31.9	+ 4
6	42.6	40.3	— 5
7	43.2	45.8	+ 6

The soil in Tanks 1 and 2 was stratified sand and clay. In the other tanks the soil was of uniform texture, a "mixture of clay, soil and fine sand". Tank 1 was covered with 30 in. of clean river sand and the water-table was always in this sand, while the others were covered with the original salt grass sod. This explains the error of the formula as applied to Tanks 1 and 2.

Where ground-water is not in evidence, the formula may be written

$$E_g = \frac{0.18}{V} M (T - 32) K \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

in which

V = Percentage of voids in the soil;

M = Free moisture content of the soil, in percentage by volume.

If the soil is shaded by crops or is covered with a mulch or well cultivated, a substantial reduction must be made. This is provided for by the factor K which has decreasing values as the crop growth advances. Since crop growth is largely influenced by temperature, the factor K may be expressed in terms of mean monthly temperature. The following is suggested for the case of diversified farm crops well cultivated:

$$K = 1 - \frac{1}{80} (T - 32) \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Percolation.—Percolation is from two sources: (1) irrigation water, and (2) precipitation.

It has been thoroughly demonstrated in practice that the amount of irrigation water lost by percolation is entirely under the control of the

irrigator, provided his supply is sufficiently elastic to permit him to adopt the proper methods of application.

In the arid regions enough percolation from both sources must occur to overbalance the evaporation from soil storage. If this is done, there can be no accumulation of alkali in the upper soil layers. Any percolation in excess of that required to prevent alkali accumulations cannot be considered a beneficial use of water.

The amount of percolation from precipitation is governed by three factors:

1.—Topography.
2.—Character of soil and crops.
3.—Amount and character of precipitation.

In the arid regions there is comparatively little loss from this source. During snowfall, percolation is deferred until snow melting occurs and the frost is out of the ground.

The following formula may be used to give approximate results for monthly values of precipitation more than 1 in.; for values less than 1 in. it may safely be assumed that there will be no loss.

$$P_r = \frac{1}{10} (R - 1) N \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

in which

P_r = percolation from precipitation, in inches per month;
R = monthly precipitation, in inches.

N is a factor having the following values:

For level or gently rolling lands of sandy loam..................	1.0
For steeper slopes of clay soils................................	0.7
For very sandy or gravelly lands............................	1.5

Percolation from both precipitation and irrigation water continues throughout the year, as evidenced by measured outflow from drains. The calculations for duty of water are greatly simplified if percolation is assumed to occur simultaneously with the evaporation losses from soil storage. After the total amount for the year has thus been determined, it may be redistributed in accordance with the following average percentages of the total:

Month.	Percentage.	Month.	Percentage.
January	4	July	13
February	4	August	13
March	6	September	12
April	7	October	8
May	10	November	6
June	12	December	5
		The year	100

Surface Waste.—This loss is also from the same two sources—irrigation water and precipitation. That from irrigation water is entirely under the control of the irrigator, and although it is possible to eliminate all loss from this source it is not practicable to do so.

Surface waste from nearly a thousand separate tracts was measured in Idaho by Mr. Don H. Bark* during his "Duty of Water Studies" for that State. As a result of these investigations, Mr. Bark states that "under Idaho conditions, from $7\frac{1}{2}$ to $12\frac{1}{2}\%$ of the amount applied should be allowed in water right contracts" for surface waste. On level or gently rolling land, about 10% may be taken as a liberal figure. On steeper lands an allowance of 15% of the amount applied may be justified. On sandy or gravelly soils, these figures should be halved, and on clay soils they should be increased one-third.

The surface waste from precipitation is generally called run-off, and is governed by the same factors as percolation from precipitation, but in different degrees. As a guide the following formula may be used:

$$S_r = \frac{3}{10} (R - 0.5) F \qquad (6)$$

Where S_r = Surface waste from precipitation, in inches per month;
R = Monthly precipitation, in inches.

F is a factor having the following values:

For steeper clay soils	1.5
For gently rolling loams	1.0
For rolling sandy soils	0.5
For level sandy soils	0.2

The monthly distribution of surface waste is concurrent with the supply.

* Reports, State Engineer of Idaho, 1911–14.

Calculation of the Net Duty of Water.

In determining the duty of water for any particular set of conditions it is necessary to consider the entire year, not the irrigation season alone. Two fundamental criteria will be advanced by which the correctness of any such determination may be judged. They are:

1.—The total quantity of water received during the mean year must be such as neither to increase nor deplete the soil storage beyond a predetermined quantity that is most advantageous to plant growth.

2.—The total amount of percolation must overbalance the evaporation originating from soil storage.

In applying the first criterion, it is necessary to determine the limits between which the soil storage may be allowed to fluctuate without harm to the plants. Then fix the amount of irrigation water to be applied such that, after adding thereto the mean precipitation and deducting therefrom the plant consumption and necessary losses, the amount of water in soil storage remains between these limits and at the end of the year has the same value as at the beginning.

The optimum free moisture content for healthy farm crops is known to be such that the soil voids are from 40 to 60% filled with water, leaving the remaining space for air.

The minimum free moisture content is a quantity that will just maintain plant growth without wilting. The wilting point was found from over 1 300 determinations,* to be such that the free moisture was one-half the hygroscopic moisture. The minimum free moisture content therefore may be safely taken as double that at which wilting occurs, or just equal to the hygroscopic moisture.

For diversified farm crops, it is only necessary to consider a depth of soil equal to the root zone of plants, and experience in farm drainage has proven that 5 ft. should be kept free of ground-water. Therefore computations may be safely based on the upper 5 ft. of soil.

What an optimum soil moisture of 60% of voids filled with water, and a minimum soil moisture of double that of the wilting point, mean, in inches of depths over 5 ft. of soil, are given in Table 3. The last two columns show the upper and lower limits between which the soil storage should be maintained.

* "Water Requirements of Plants", *Bulletin 285*, Bureau of Plant Industry, U. S. Department of Agriculture, 1913.

TABLE 3.—Optimum and Minimum Free Moisture in 5 Feet of Typical Soils, Expressed as Depth in Inches on the Land.

Soil.	Percentage of Voids.	Optimum free moisture content.	Minimum free moisture content.	
Coarse sand	36	13.0	0.5	
Fine sand	38	13.7	1.8	
Sandy loam	40	14.4	3.9	
Fine sandy loam	45	16.2	5.3	
Loam	48	17.3	6.8	
Clay loam	50	18.0	8.2	
Clay	52	18.7	8.5	

Some of the coarser soils will not hold the optimum moisture content by capillarity. Hence, it is a decided waste of water to try to maintain a moisture content greater than the capillary capacity of the soil in question.

The second criterion is based on the fact that in humid regions where the percolation exceeds soil evaporation, there are no surface accumulations of alkali. On the other hand, such accumulations are always in evidence wherever the upward movement of water in the soil is not overbalanced by the downward movement.

With these two criteria as a guide, it is possible to determine the amount of water required to maintain any desired degree of soil moisture, which, in effect constitutes the net Duty of Water. This quantity is the amount required to balance the receipts and disbursements of water on the land during the mean year.

The physical factors that must be known in advance are:

1.—Soil characteristics as to porosity, height of capillary rise, capillary capacity, depth and uniformity of texture.

2.—Topography.

3.—Mean monthly and mean annual temperature.

4.—Mean monthly and mean annual precipitation.

5.—Probable crops and yields.

In making the calculations we may first arrive at approximate values by using the mean annual climatic factors.

Let R = Mean annual precipitation;

I = Irrigation water to be applied (net duty);

C = Total annual plant consumption;

P_i and P_r = Total annual percolation loss from irrigation water and from precipitation, respectively;

S_i and S_r = Total annual surface waste from irrigation water and from precipitation, respectively;

E_i, E_r, E_g = Evaporation from irrigation water, precipitation and soil storage, respectively.

Balancing the total water receipts and disbursements on the land, we may write:

$$I + R = C + (P_i + P_r) + (S_i + S_r) + (E_i + E_r + E_g) \ldots \ldots (7)$$

In this expression, R and C are known, independent quantities, E_r, P_r and S_r may be found in terms of R; also E_i and S_i may be expressed in terms of I. From the second criterion, we also have:

$$P_r + P_i > E_g \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (8)$$

But as E_g is itself a function of both I and R and the monthly temperatures, a tentative solution only is possible.

It will be found that the net duty, I, will be given in terms of either average soil moisture content or of the position of the water-table, which in turn is an index of the soil moisture above it.

Hence, if we can determine the most advantageous soil moisture content for the particular case in hand, we may fix I, the net duty of water.

Calculated Duty for the Boise Project, United States Reclamation Service.

The application of the foregoing principles will be illustrated by a concrete example. The Boise Project in Idaho will be used, since the duty of water there has been fairly well determined.

Plant Consumption.—The crop statistical reports of the United States Reclamation Service were averaged for the years 1914-1917 inclusive. The acreage used is that of 1917. The plant consumptions as determined at Akron, Colo., were applied without reduction for climatic differences.

As shown in Table 4, a mean plant consumption of 1.06 ft. or 12.7 in. per year was indicated. In distributing this amount it is assumed that growth begins on April 1st, and that the distribution is proportional to the increase of mean monthly temperature over that of March, as in Table 5.

TABLE 4.—AVERAGE PLANT CONSUMPTION, BOISE PROJECT.

Crop.	Acres.	Yield per acre.	Plant Consumption.	
			Depth, in feet.	Acre-feet.
Alfalfa	34 090	3.9 tons	1.66	56 800
Barley	3 220	20.4 bu.	0.50	1 610
Clover	7 680	2.03 tons	0.84	6 430
Corn	1 410	37.9 bu	0.97	1 370
Mixed hay	510	1.4 tons	0.62	320
Oats	3 210	25.5 bu.	0.48	1 540
Pasture	6 550	....	0.50	3 280
Wheat	25 680	21.2 bu.	0.63	16 100
Total	83 350	....	1.06	87 450

TABLE 5.—DISTRIBUTION OF MEAN PLANT CONSUMPTION.

Month.	Mean monthly temperature, T.	$T - 42$	Percentage of total.	Inches.
March	42	0	....	....
April	50	8	6	0.8
May	58	18	13	1.6
June	66	24	17	2.2
July	73	31	22	2.8
August	72	30	22	2.8
September	62	20	14	1.8
October	50	8	6	0.7
The season	......	139	100	12.7

Precipitation.—The losses from precipitation and the net amount going to soil storage are next found from Formulas (1), (3) and (4), as in Table 6.

TABLE 6.—TOTAL LOSS AND AMOUNT OF SOIL STORAGE.

Month.	R	T	E_r	P_r	S_r	Total lost.	To soil storage
January	1.9	29.3	0.4	0.1	0.4	0.9	1.0
February	1.4	33.8	0.4	0.0	0.3	0.7	0.7
March	1.4	42.2	0.5	0.0	0.3	0.8	0.6
April	1.2	50.1	0.5	0.1	0.2	0.8	0.4
May	1.3	57.6	0.7	0.0	0.2	0.9	0.4
June	0.9	66.0	0.6	0.0	0.1	0.7	0.2
July	0.2	72.8	0.2	0.0	0.0	0.2	0.0
August	0.2	71.8	0.2	0.0	0.0	0.2	0.0
September	0.4	61.9	0.4	0.0	0.0	0.4	0.0
October	1.3	50.3	0.6	0.1	0.2	0.9	0.4
November	0.8	39.6	0.3	0.0	0.1	0.5	0.4
December	1.8	32.2	0.4	0.1	0.4	0.9	0.9
Total	12.8	50.6	5.2	0.4	2.2	7.8	5.0

Soil Evaporation.—This is found from Formulas (3) and (4). The soil is assumed to average 5 ft. in depth and to be of level or gently rolling sandy loam. An average soil porosity of 40% was used. The water-table was assumed to be either naturally, or kept by drainage, below the 5-ft. level.

The monthly expressions for evaporation from soil storage are thus found as in Table 7.

TABLE 7.—MONTHLY EVAPORATION FROM SOIL STORAGE, E_g.

Month.	$T - 32$	K	E_g
January	0.0	1.00	0.0
February	1.6	0.98	0.7 M
March	12.2	0.85	4.6 M
April	18.1	0.78	6.3 M
May	25.4	0.64	7.3 M
June	34.0	0.58	8.9 M
July	40.8	0.49	9.0 M
August	39.8	0.51	9.1 M
September	29.9	0.64	8.6 M
October	18.3	0.77	6.3 M
November	7.6	0.91	3.1 M
December	0.2	1.00	0.0
The year	17.6	0.76	5.36 M

The last column shows the multipliers of the average monthly free soil moisture content, M, to obtain the soil evaporation for that month.

In order definitely to fix the amount of irrigation water to be applied, first fix the desired average amount of soil moisture to be maintained. The distribution of moisture in the soil is anything but uniform, and there is always a movement of moisture from the wet to the dry soil by capillary action. It is only practicable, however, to consider the average monthly free moisture content in these calculations.

Now substitute in Equation (7) the values already determined, and, since P_r is small, place $P_i = E_g$, also E_i and S_i each equal 0.1 I, to obtain the net duty in terms of average soil moisture:

$$I = 2.5\ E_g + 9.5 \qquad (9)$$

Now substitute for E_g twelve times its mean annual value and

$$I = 160\ M + 9.5 \qquad (10)$$

From Equation (10) it is evident that to maintain an average soil moisture of 10%, or $M = 0.1$, requires 25.5 in. of irrigation water; 12½%

requires 29.5 in., and 15% requires 33.5 in. These, however, are only tentative values for selecting a trial value of I.

The proper average soil moisture for the standard farm crops is a fruitful line of research on which there are little or no actual data. It is believed for the case in hand that an average soil moisture of 12 to 14% should be maintained, hence a trial value of $I = 30$ in. will be taken with the monthly distribution indicated in Table 8.

TABLE 8.—MONTHLY DISTRIBUTION.

Month.	Percentage of total.	I.
April	4	1.2
May	12	3.6
June	18	5.4
July	23	6.9
August	24	7.2
September	13	3.9
October	6	1.8
	100	30.0

Now deduct the plant consumption and all determined losses from the sum of R and I; the remainder is the amount lost by soil evaporation and percolation of irrigation water. In the first calculation, P_i and E_g are assumed to be concurrent losses. A probable value for soil moisture for April is assumed as desirable at the beginning of the irrigation season. This percentage of soil moisture is applied to the multiplier for E_g (Table 7) in order to obtain the value of E_g for the succeeding month. Double this quantity ($2\ E_g$) is then deducted from the remainder available for P_i and E_g, to obtain the increment or decrement to soil storage which, in turn, gives the soil moisture increment or decrement from which the average soil moisture for the next month is obtained. In this manner, by repeated trials, a value of soil moisture at the beginning of the season is found such that the total soil evaporation E_g is equal to half the remainder available.

The monthly values of soil moisture must remain within the prescribed limits of optimum and minimum values heretofore established and the algebraic sum of the increments thereto must be zero. If this cannot be obtained with the assumed value, a new value of I is tried until a value is found that will balance the receipts and disbursements of the soil, maintain the soil storage between the prescribed limits and

neither increase nor deplete the total soil storage during the year. After this is found the percolation loss is redistributed by months in accordance with the schedule of monthly percentages previously given, and the necessary adjustments in soil moisture are made.

Table 9 shows the balance sheet for the Boise Project so obtained; and in Fig. 1 the principal data are shown graphically.

TABLE 9.—BALANCE SHEET, BOISE PROJECT.

Month.	RECEIPTS.	DISBURSEMENTS.					Percentage of average soil moisture.
	$I + R$, in inches.	Evaporation $E_r + E_i + E_g$, in inches.	Percolation, $P_i + P_r$, in inches.	Surface waste, $S_r + S_i$, in inches.	Plant consumption, C, in inches.	Total, in inches.	
January....	1.9	0.4	0.4	0.4	....	1.2	13.4
February..	1.4	0.5	0.35	0.3	....	1.15	13.8
March......	1.4	1.15	0.5	0.3	....	1.95	12.9
April........	2.4	1.4	0.65	0.3	0.8	3.15	11.7
May.........	4.9	1.95	0.8	0.6	1.6	4.95	11.8
June.......	6.3	2.15	1.0	0.6	2.2	5.95	12.2
July........	7.2	2.0	1.05	0.7	2.8	6.55	13.1
August.....	7.4	2.1	1.05	0.7	2.8	6.65	14.3
September..	4.2	2.0	1.0	0.4	1.8	5.2	12.8
October....	3.1	1.6	0.75	0.4	0.7	3.45	12.2
November..	0.8	0.7	0.5	0.1	....	1.3	11.4
December..	1.8	0.4	0.5	0.4	....	1.3	12.2
The year..	42.8	16.35	8.55	5.2	12.7	42.8	12.7

Summarizing the various quantities, Table 10 is obtained.

TABLE 10.—SUMMARY.

	Depth, in inches.		Percentage of total.
RECEIPTS:			
Irrigation water..............................	30.0	....	....
Precipitation..................................	12.8	42.8	100
DISBURSEMENTS:			
Plant consumption......	12.7	....	30
Evaporation.................. E_g 8.15			
E_r 5.2			
E_i 3.0	16.35	....	38
Percolation.................. P_r 0.4			
P_i 8.15	8.55	...	20
Surface waste............... S_r 2.2			
S_i 3.0	5.2	....	12
Total....................................	....	42.8	....
Total losses...........................	30.1	....	70

Note that the total percolation loss of 8.55 in. overbalances the soil evaporation loss of 8.15 in. by 5%, and that all the other criteria outlined are complied with.

In order to judge of the consistency of these figures, a study was made of the actual use of water and crop statistics of three projects of the United States Reclamation Service for the four years 1914-1917, inclusive, with the results given in Table 11.

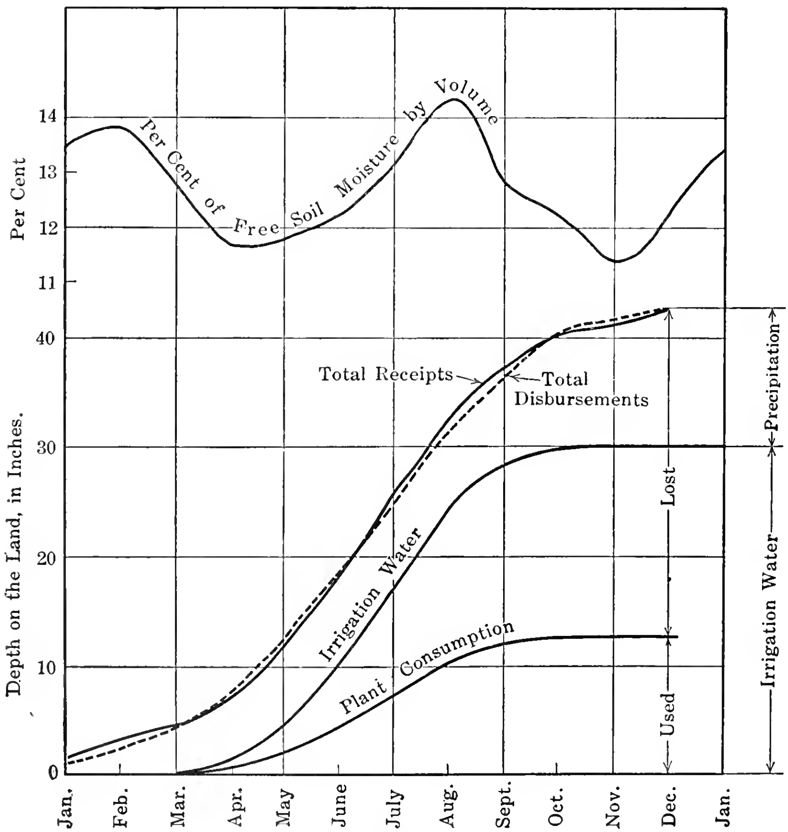


FIG. 1.

On the Klamath Project only 48% of the total water received was lost. The soil on this project is such that the danger of waterlogging the land has led the irrigators to use a comparatively small quantity of water, about 1.0 ft. being artificially applied.

On the Boise Project the average water received was 42.5 in., of which 72% was lost. In the previous analysis, a total receipt of 42.8

TABLE 11.—SUMMARY OF CROP YIELDS, WATER RECEIVED AND DISBURSED ON THREE U. S. RECLAMATION SERVICE PROJECTS.

Project.	Year.	Acreage reported:	Total water received, in feet.*	Plant consumption, in feet.	Losses.	
					Depth, in feet.	Percentage of total.
Klamath	1914	23 850	1.51	0.77	0.74	49
	1915	26 810	1.41	0.69	0.72	51
	1916	29 020	1.29	0.63	0.66	51
	1917	32 510	1.13	0.73	0.40	35
	Mean	28 050	1.34	0.70	0.64	48
Boise	1914	54 290	3.09	0.87	2.22	72
	1915	66 400	3.38	0.96	2.42	72
	1916	47 830	4.10	1.17	2.93	71
	1917	82 350	3.65	1.06	2.39	71
	Mean	67 720	3.55	1.01	2.54	72
Truckee-Carson	1914	38 330	3.38	0.98	2.40	71
	1915	37 610	3.29	0.90	2.39	73
	1916	38 250	3.42	1.01	2.41	70
	1917	37 190	3.20	1.06	2.14	67
	Mean	37 850	3.32	0.99	2.33	70

* Includes precipitation.

in. was determined as necessary, of which 70% is lost. Of this amount 12.8 in. is precipitation and 30 in. is irrigation water. The agreement between the theoretical requirements and the average used during the four years is striking.

Mr. Bark's conclusions are that: "The duty for projects planted to diversified crops on the average clay loam soils of South Idaho should be sufficient so that 2 acre-feet can be retained on each irrigated acre" and that a waste of 12½% should be provided to individuals over and above that amount. This makes 27 in., which is comparable with the analytically determined duty for the Boise District of 30 n.

In conclusion it is well to remember that no hard and fast rules can be laid down, and exact formulas cannot be devised. Such an analysis as that here outlined is a study in nice approximations in which consistency and common sense play important parts. Such analyses are necessarily based on the average, or mean climatic, year. No season exactly parallels the mean year. In dry years the amount of irrigation water should, theoretically, be increased and during wet years it should

be reduced. These yearly variations, however, can rarely be taken into consideration in the design of irrigation works. The only practicable method is to base the design on the mean requirements and add a margin of safety for contingencies.

In the application of water to crops, there is a growing tendency to follow more scientific methods and thus eliminate unnecessary waste. The amount of soil moisture is the best possible index of the necessity for irrigation and also of the amount to be applied. Heretofore this index has not been generally used because of the difficulty with which the amount of soil moisture could be determined. In this connection, it is perhaps fitting to add that the writer has recently designed a soil moisture indicator. This instrument is intended to be placed in the ground permanently, and indicates at the surface the relative amount of free moisture in the soil at any desired depth.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

WATER SUPPLY FOR THE CAMPS, CANTONMENTS, AND OTHER PROJECTS BUILT BY THE CONSTRUCTION DIVISION OF THE UNITED STATES ARMY

Discussion*

By Dabney H. Maury, M. Am. Soc. C. E.†

Dabney H. Maury,‡ M. Am. Soc. C. E. (by letter).‖—Mr. Dunham¶ asks whether, with the experience thus far gained, the writer would, on a similar demand for advice to the Government, recommend the same per capita allowance. To this the writer would unhesitatingly reply that, under similar conditions, he would. This answer should not, however, be construed to apply without exception to all sorts of Government activities, in peace as well as in war. Mr. Maury.

In time of peace, restrictive regulations and military discipline generally are apt to be less rigidly enforced than in time of war. Furthermore, in time of peace it is exceedingly unlikely that any army post would be garrisoned to its full capacity, and it was observed in every case that as the number of men at any camp was reduced, the per capita consumption increased, and *vice versa*.

The capacity of the water system should be great enough to give each man his proper daily allowance, assuming the camp to be fully occupied. Then, if a large number of men are ordered away, it is to be expected that the per capita consumption will increase, because all the leakage and part of the waste will continue as before; but there

* Discussion of the paper by Dabney H. Maury, M. Am. Soc. C. E., continued from January, 1920, *Proceedings*.

† Author's closure.

‡ Chicago, Ill.

‖ Received by the Secretary, February 13th, 1920.

¶ *Proceedings*, Am. Soc. C. E., September, 1919, p. 664.

Mr. Maury. will still be enough water for the men remaining, and the increase in per capita consumption will not have nearly so bad an effect as would be the case if it resulted in an actual shortage of water.

It was the writer's observation that, as a rule, the per capita consumption at the older and permanent posts was extravagantly high, often several hundred gallons per day. This was due in part to the large quantities of water used for lawn sprinkling; in part to seriously defective plumbing, especially in Coast Defense Fortifications, where brackish water had caused many leaks; and in part to waste of water in the officers' quarters.

What a man gets for nothing, he neither appreciates nor conserves. If all the officers' quarters were metered, with water furnished free to the amount of, say, 50 gal. per day for each occupant of the quarters, and a good stiff meter rate added for all water used in the quarters in excess of that allowance, much could be accomplished in the way of reducing the consumption at these army posts.

The writer is well aware, however, that the enforcement of this regulation would add nothing to the popularity of the already much-abused Utility Officer, and that for a few days after rendering his monthly water bills, he might feel tempted to absent himself from the officers' mess and club.

In reply to Mr. Dunham's second question, the writer would state that the water-works systems of the cantonments were designed to furnish, in addition to one-quarter of the peak rate of domestic consumption for a fully occupied camp, water for fire purposes at the rate of 2 000 gal. per min., at a net pressure of not less than 50 lb. per sq. in. at any group of hydrants on the distribution system. The fire-drill regulations made it the definite duty of certain designated individuals to shut off, as soon as the fire alarm was sounded, every fixture from which water might be drawn for purposes other than fire-fighting, except those necessary for cooking purposes. There were two principal mains, 480 ft. apart, running through each regimental unit, with hydrants spaced only 215 ft. apart on each main, so that twelve streams could be concentrated on any building between the mains, without laying any line of hose longer than 350 ft. The shortness of the lines of hose and the use of small hose nozzles, only $\frac{7}{8}$ in. in diameter, combined to give very small friction losses through the hose. There was good separation of buildings—40 ft. between two-story buildings, and 30 ft. between one-story buildings or between a one-story and a two-story building. There were also fire gaps of 300 ft. between brigade units or groups of buildings. Plenty of men were available, of course, to handle the hose and the hydrants.

The net effect of all these specifications was that any building could be attacked from many different directions by a large number of fire streams, with good nozzle pressure and good horizontal projection

Mr. Maury.

of stream. The results obtained in extinguishing fires and in keeping down fire losses were summarized in the writer's paper.*

Mr. J. Waldo Smith† asks whether the writer would recommend the form of contract used in building the cantonments for general adoption in time of peace.

That form of contract was unquestionably the only one under which the cantonments could have been constructed within the time allowed. Its development was almost a stroke of genius on the part of the members of the Advisory Committee referred to by the writer;‡ and this is especially true if genius be defined as "an infinite capacity for taking pains", for that contract represented weeks of the most careful study by some of the brightest minds of the Profession.

The writer, however, concurs in Mr. Smith's opinion that the cost-plus-a-fixed-fee contract is not one which should be universally adopted for all construction in time of peace, and especially where speed is not of vital importance.

In conclusion, the writer fully realizes his good fortune in having had his paper discussed by so many of his personal friends, and he would again remind his readers that the design and construction of the water-works for the army activities were in no sense a one-man job, and that the credit for such results as were obtained should be shared by all the many men who had a hand in the work.

* *Proceedings*, Am. Soc. C. E., August, 1919, p. 443.

† *Proceedings*, Am. Soc. C. E., September, 1919, p. 655.

‡ *Proceedings*, Am. Soc. C. E., August, 1919, p. 400.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

GROUTING OPERATIONS, CATSKILL WATER SUPPLY

Discussion*

By Messrs. Robert Ridgway, J. Waldo Smith, Lazarus White, John P. Hogan, Francis Donaldson, Waldo C. Briggs, A. J. Sackett, Andrew A. Cohill, and A. J. Mayell.

Robert Ridgway,† M. Am. Soc. C. E.—The speaker wishes to express his appreciation of the great value of this paper to constructing engineers. Not only is the subject one of much importance, but the authors are especially qualified to present the paper because of their first-hand knowledge of the operations which they describe. Its value is enhanced by the fact that it was prepared while the work was still fresh in mind, in consultation with those familiar with all the details of the operations and with all the records available. Many lessons learned at great cost on works of construction are lost to those who take up similar work at a later period because the organization that learned and applied them is broken up on completion of the work, leaving behind only what a recent writer has described as "dead and fragmentary records" which are practically lost when they are filed away in some vault for safe keeping. The construction of large water supply systems like those of the Catskill project is not a continuous performance. Sometimes there are intervals of many years between the completion of one project and the beginning of another, and the earlier work is largely forgotten when the later one is undertaken. If a record of the unusual features of design and construction is not left behind in some such form as the paper under dis- Mr. Ridgway.

* This discussion (of the paper by James F. Sanborn and M. E. Zipser, Associate Members, Am. Soc. C. E., published in January, 1920, *Proceedings*, and presented at the meeting of February 4th, 1920), is printed in *Proceedings*, in order that the views expressed may be brought before all members for further discussion.

† New York City.

Mr. Ridgway. cussion, those who take up similar studies at some future time must go over the same ground and inevitably make some of the same mistakes as their predecessors.

The grouting methods of the Catskill work were highly developed, and were successful as a result of a willingness to experiment in practical ways and of the large experience gained on a work of such magnitude and varying conditions. It is extremely fortunate, therefore, that this interesting paper has been prepared describing the methods adopted, and it is hoped that the Chief Engineer will suggest to his staff the preparation of other equally valuable papers descriptive of such features of the work, for example as the deep pressure tunnels for which there was little precedent in earlier projects.

The speaker's first experience with grouting was in the grade tunnels of the so-called New Croton Aqueduct during the years 1888 to 1890. This tunnel was lined with brick backed with rubble masonry. The brickwork and rubble were laid at first in natural cement mortar, but in the later stages of the work Portland cement mortar was used. On account of the unfortunate conditions then prevailing, for which the engineers were in no way responsible, it became necessary to repair long stretches of defective masonry lining. It was the practice of some of the contractors to omit most of the mortar in the rubble masonry and in some cases to omit the rubble masonry altogether. The scamp work was done in such a wholesale manner that it was necessary to organize for the repairs in a comprehensive way. Where the brickwork was defective and where there existed large voids in the backing, it was of course necessary to tear out and rebuild. Where it was a case of supplying the mortar in the rubble backing it was decided, after considerable discussion and experimenting, to resort to grouting methods.

An experimental period had to be passed through at first. Holes were drilled through the brick side-walls and a thick mixture of grout was poured into them by means of funnels. This method, of course, could not be adopted in the upper portions of the arch, nor could any pressure be applied to the grouting. Besides, it was a retail way of doing a wholesale job and was soon discarded.

The method later adopted, and which proved to be successful for the work in hand, required the use of hand-operated Douglass pumps. A 1 : 1 mixture of natural cement and sand was mixed by hand in open boxes and pumped through holes drilled in the brickwork. Natural cement, or as it was then called, "American" cement, was used because much of the masonry was specified to be laid with that cement. In order to insure practically continuous pumping two boxes were used, the mixing going on in one while the charge was being pumped from the other. A set of nine holes was drilled every 10 ft. in the side-walls and the arch. The metal nozzle of the discharge hose, wrapped with cloth or

Mr. Ridgway.

burlap, was driven into these holes and the grout was pumped in to refusal. Usually four men were used at the handles of the pumps, the number being increased to six when the pumping was hard. The lower holes on each side were grouted first and the key holes last. The grout was driven long distances, sometimes several hundred feet, and frequently was lifted over the arch from the lower holes in the side-walls. Grouting in one hole frequently blocked many others, but the latter were subsequently tried and sometimes took an appreciable amount of grout.

Prior and subsequent to the first grouting the masonry was carefully sounded with steel rods for indications of cavities or other defects. Those engaged on such work soon became very expert and could tell in a general way from the tone given out by the rod whether or not the brickwork and its backing were defective. Where the soundings or the drill holes, together with the cross-sections, indicated the existence of large cavities, or where the brickwork was defective, test holes were cut and the defective work removed and rebuilt as far as necessary before any grouting was done in the vicinity. After the first grouting, another set of holes was drilled and grouted where soundings indicated that further work was necessary. Again the work was sounded and a third grouting was done in the limited number of places requiring it.

In the report of the Aqueduct Commissioners for 1887 to 1895 is a general description of this grouting by the Chief Engineer, and a statement is made by him that 384 700 bbl. of cement in all were used for grouting, exclusive of the cement used for the reconstruction of defective or missing masonry by hand. Of this amount probably 15% was wasted through leakage and other causes. As the purpose of the work was to fill voids in the masonry backing, no attempt was made to grout seams in the rock. The methods were crude as compared with those used on the Catskill work, but accomplished the results desired. While the voids were almost completely filled with grout it appeared from the speaker's observations that the latter did not set up well. Samples taken out by the speaker a year or so afterward showed the natural cement to be of chalky consistency, with little strength. Apparently, natural cement is not suitable for grouting work except in cases where its function is merely to fill voids. Where strength and density are essential requirements only Portland cement should be used.

Grout was used extensively and successfully in the construction of the tunnels of the subway system of New York City. This grouting was important, but generally speaking it was not of such difficult character as that of the Catskill work. In earth and rock tunnels, grouting was done to fill the voids which always exist over the concrete arch and to reduce leakage. It was done in the soft ground shield-driven tunnels adjacent to the East River to prevent settlement of ground overhead, and where the work was done in compressed air under and in the vicin-

Mr. Ridgway. ity of the East River to reduce the loss of air from the tunnels. The methods have been quite successful in accomplishing these objects. The pressures used have not been high, corresponding to those used in the "low-pressure" grouting described by the authors.

Within the past year, grouting was successfully used to reduce the leakage in the Canal Street Station of the New York Municipal Railway subway from considerably more than 100 gal. per min. to less than 2 gal. per min. The work was of a most difficult nature and the excellent results were accomplished only because the engineers in direct charge were possessed of an intimate knowledge of modern grouting methods and their limitations. The speaker will not go into the details, as he understands that they have been covered in the written discussion by A. J. Mayell, Assoc. M. Am. Soc. C. E., who was the Assistant Division Engineer on the work. The guidance of M. H. Freeman, M. Am. Soc. C. E., formerly of the Engineering Staff of the Board of Water Supply, was invaluable on this work.

It is apparent from the authors' description that the concrete of the tunnel and shaft lining is of excellent quality, due to the great care taken in placing it. Otherwise, the speaker is convinced that the grouting would not have been a success. To accomplish the results described it was essential that the concrete be strong and dense. Grouting will not change poor concrete into good concrete and it adds little or nothing to the strength of poor concrete. To obtain good concrete it is necessary not only to mix it properly, but to keep all water pressure away from it while setting. It will be porous unless this is done, as many engineers have found when they did not take proper precautions.

Grouting is expensive, and to secure the best results at the least cost and in the quickest time it is wise to employ only those experienced in such work. To start with an untrained force usually results in discouragement and sometimes the abandonment of the work. After the men are well broken in they seem to develop an instinct for doing the work in the right way in the shortest time and accomplish what before seemed to be impossible.

If the grouting work under a contract is to be done as carefully and as thoroughly as it was on the Catskill work it is necessary to draw the specifications with care and to make provision, as was done on that work, to pay the contractor for each step in the operations. For example, the cost to the contractor of moving the apparatus and of making connections to the grout pipes is considerable and sometimes many connections are made to pipes which take no grout. If payment is made merely on the basis of grout pumped in, this would work a hardship on the contractor who would receive no payment for the work done on those holes into which no grout was forced. In the case of the Catskill work payment was made under unit prices for each connection made.

The authors state, referring to the cement, "experiments show that the finer the grinding, the greater the loss in the strength of the grout on account of the more thorough hydration of the cement. The coarse particles impart strength to the cement, and, for that reason, very fine grinding may not be desirable." This is interesting, and contrary to the idea of the speaker, who had been of the opinion that finely ground cement would be better for this and for all other purposes. Where sand is used it must be very fine, as the authors point out, to prevent segregation as well as clogging of the holes. Mr. Ridgway.

In the discussion preceding the preparation of the Catskill tunnel contracts the speaker favored the cut-off walls mentioned by the authors. It was believed that by confining the grouting to relatively short stretches of tunnel and completing each stretch before passing to another the cement and sand would not segregate and that better results would be obtained. Experience, however, showed that they did not work out well in practice and hence their use was discontinued.

The authors point out the care necessary to prevent a blast of air following the charge of grout where the tank machines are used. Where small spaces are to be filled completely and the amount of grout, consequently, is small, it has been found advisable in many cases to use a hand pump, thus avoiding the objection of trapping in the cavity air which prevents complete filling of the hole.

It has been assumed by many that grouting could be used to solidify unstable sand foundations, particularly where the sand is fine and saturated. The speaker has seen a number of unsuccessful attempts made to do this. Perhaps with infinite pains and at great expense something could be accomplished in this direction, but he does not believe it to be a practical proposition.

As of interest in connection with the treatment of dam foundations attention is called to the paper of Charles S. Gowen, M. Am. Soc. C. E., entitled "The Foundations of the New Croton Dam",* wherein is described the novel method used to fill with clay the voids existing in a limestone cave under the dam. Plastic clay in the form of "sausages" or cylinders was fed into a casing pipe which had been carried up from the cavity 100 ft. or so and bedded in the masonry of the dam. The clay was driven by means of a pile-driver. The details are well described in Mr. Gowen's paper, and it is stated that a total of 66 951 lb. of clay was driven, apparently completely filling the cavity, as evidenced by the rising of the clay in a tell-tale pipe outside of the dam structure. In the speaker's opinion the method thus described could be used in many cases where the problem is merely to fill voids with a water-tight material and where it is not necessary to use material that will solidify like cement.

* *Transactions*, Am. Soc. C. E., Vol. XLIII, p. 469.

Mr. Smith.

J. Waldo Smith,* M. Am. Soc. C. E.—This paper is a creditable record of many years of work under greatly varying conditions. The widely diversified aqueduct work provided an opportunity for the development of new ideas, and the 35 miles of pressure tunnel offered a much better opportunity than has before presented itself for the further development and perfecting of grouting methods. Due to the great number of men engaged on it and the variety of ideas that were presented, it is safe to say that more has been done to develop and put on record methods that will be useful in the future to those undertaking such work than ever before.

It is part of every one's duty to place in the archives of the Society records of methods that have been developed, for the benefit of others coming after or which will help the wayfarer looking for assistance along the road. Mr. Ridgway has stated that he hoped the speaker would suggest other papers. He has done so; but, due to the war and perhaps also to the fact (which should be a matter for congratulation) that in most cases the men best suited to write these papers have gone on to better positions before their work was finished and before they had time to do so, the proposed papers have not been prepared.

The speaker still hopes that some of the men, although they are no longer connected with the work, will undertake to present a series of papers which will cover all the special features of the Catskill Aqueduct. The one that he wants to see more than any other is a comprehensive paper on the pressure tunnels, because the pressure tunnels, the grouting of which is so fully described in this paper, were among the principal features of this work.

If the speaker had undertaken to have a number of the engineers submit the data and had himself prepared this paper, he is sure he would have been very unhappy. He could not have done it as well as they have, and it is much better for those who have been close to the work and who have really done the work, to obtain whatever glory or credit or publicity may come to them through the presentation of such a paper as this.

The authors have said that this paper was prepared at the speaker's suggestion. Well, such suggestions are part of his religion. He believes that a man in the position he has been in owes it to his associates (there have been no assistants on this job) to see that they have a chance to develop, and to help them onward and upward. It is the duty of all the members of the Society who are in executive positions to do what they can to develop the younger men, to allow them to accept responsibility, or to force it on them. To place such responsibility brings results which would be beneficial to any project.

Mr. White.

Lazarus White,* Assoc. M. Am. Soc. C. E.—This paper is so thorough and covers the subject so well that it is difficult to enlarge upon

* New York City.

it. There is one impression which the authors did not intend to convey, but might be obtained due to the great emphasis on the grouting operations; that is, that the water-tightness of the tunnel was due almost entirely to the grouting, and that the concrete tunnel lining itself is of minor importance. This, in the opinion of the speaker, would be unfortunate, for, as Mr. Ridgway remarked, the tunnel lining itself is of primary importance and without a thoroughly good lining it would be hopeless to secure water-tightness for effective grouting. Those who examined the tunnel will bear witness to the fact that the lining was first-class with very few visible defects. To get good lining, every care was taken in leading the water off with drip-pans and grout pipes, as the authors describe. This prevented damage to the lining; allowing the concrete to set while it was entirely relieved of water pressure and water percolation. The same drip-pans and grout pipes which primarily served to lead off the water and protect the lining were the instruments for the subsequent grouting. Mr. White.

Had the vent pipes been blocked, the lining itself would be found to be very tight without the grouting. In one instance this was done, and the lining withstood a pressure of 135 lb. per sq. in. without leakage. This was described by the authors. The grouting, in the opinion of the speaker, was primarily designed to back up the lining, and to transfer the internal pressure through the concrete and grout to the rock backing. It is the rock in pressure tunnels which, after all, carries the pressure, and it must necessarily carry it. In cases where sections of the tunnel lining failed, it was due to the fact that the rock backing was unable to carry the heavy internal pressure. On the Rondout Tunnel there were heavy layers of limestone between which were layers of greasy clay, and when the internal pressure was applied, the strata moved, cracking the lining. These stretches were repaired by putting in steel lining capable of withstanding the internal pressure without the aid of the rock.

As the authors have stated, there were people who predicted that the lining would fail in very numerous cases, and favored the use of a continuous steel lining to take up the internal pressure independently of the rock. It was decided that this would be too expensive, and it would be cheaper to test the tunnels hydrostatically and repair the weak spots in places where that was necessary. This was done and resulted in great economy.

It is to be noted that the grouting operations at the end of the work were quite different from those at the beginning, and much simpler. An elaborate arrangement of grout pipe, drip-pans, cut-off walls, collecting pipes, etc., which were at first shown in the design, were later dispensed with. The grouting methods which were subsequently used in the aqueduct were the result of a great deal of experience and developed from many years of work.

Mr. White. The impression might be given from the statement by the authors on page 60* that the grouting behind the pneumatic caissons was responsible for their tightness when the air was taken off. The sealing of these caissons was accomplished by the simple expedient of dropping them on a bench of concrete so that the cutting edges compressed a heavy wad of oakum. Immediately after this the air was withdrawn, and the caissons were very dry. The grouting subsequently done behind the caissons was in the nature of backing them up and making more permanent the sealing accomplished by the oakum.

Mr. Hogan. JOHN P. HOGAN,† M. AM. SOC. C. E.—This paper is so complete in itself that there is very little that can be added to it. The only thing that any one can do in discussing it is to attempt to emphasize or bring out more strongly some of the points covered.

Of the points that the speaker would like to emphasize is one which Mr. White also has made, that in order to be successful grouting must be simple. Complicated systems of connecting pipes and elbows, leading a large amount of water to a given point, and attempts to grout a large area during one operation, never succeed. Straight pipes and small drip-pans are needed. A small drip-pan is necessary for two reasons: first, in order that it may be grouted successfully, and, second, to avoid bringing too large an area of the tunnel lining under pressure. The latter requirement became very important in high-pressure grouting, particularly in the Hudson River Siphon, where a grouting pressure of 700 lb. per sq. in. was used. In some cases on that work where the lining ruptured, there was evidence that the drip-pans were too large, and too large areas of the tunnel lining were exposed to the high pressure grouting.

The statement is made by the authors that the purpose of low-pressure grouting was: "(*a*) primarily to fill the void spaces between the lining and the rock, particularly above the arch, and, at the same time, to form a blanket over the construction joints in the arch; (*b*) to fill the voids in the dry-packing where the latter was used; and (*c*) to fill any porous or honey-combed spots in the concrete." If anybody has had any success in filling porous or honey-combed spots in concrete with grout, the speaker would like to know about it, because, for about six weeks, experiments were made in the Rondout Siphon to impregnate leaky concrete with grout. The Board provided for this purpose a special grouting pad 2 ft. square and consistent and persistent efforts were made to use it, with a total net result of loss of time and loss of money. The attempt to grout leaky concrete with this pad was like trying to use an irresistible force against an immovable resistance.

The speaker merely mentions this because the authors have carefully avoided any further mention of it in the paper. One does not get grout

* *Proceedings*, Am. Soc. C. E., January, 1920.

† New York City.

Mr. Hogan

in place anywhere unless one has circulation. The simplest form is the grout pipe and the vent pipe; when you get grout out of the vent pipe, you know the intermediate space is filled. In the same way in filling grout seams, wherever there was any interconnection and circulation through the seams it was possible to get grout into the seams; but, in general, very little progress was made in attempting to grout the seams in the rock unless there were such interconnections.

The provision of sufficient vent pipes for circulation and for getting rid of surplus water and air also enables you to see what you are doing and what you are accomplishing.

It has been correctly stated that the lining and not the grouting was the primary cause of the tightness of the tunnel. The important thing in placing a tight lining is to prevent water pressure on the concrete while it is setting. It is therefore necessary to lead water through the concrete to prevent the accumulation of pressure, and it is necessary in some way to fill the void which existed for the purpose of collecting water. If it were not for the sake of permanency, the pipes leading through the concrete for the purpose of collecting water might be closed with an iron cap, or even possibly with a wooden plug. The grout forced in through these pipes, however, in addition to stopping permanently the inflow and plugging the pipe, helps to back up the lining over the area which the drip-pan covers.

In grouting on a large scale, special provision must be made for carrying the grouting pipes through the forms, particularly when steel forms are used. This was done on the Catskill Aqueduct by threading holes through the forms, and by leaving couplings on the ends of pipes, so that connections could be made to them readily.

In grouting large spaces, such as existed in the dry packing back of the steel shell on the Rondout incline, special measures are necessary. In the incline, at the time the concreting was started, there was an inflow of 1 200 gal. per min. of water within a stretch of about 180 ft. The placing of the invert was the most difficult operation on account of the necessity of caring for the water in the bottom, while the invert concrete was setting. This was successfully accomplished by laying a longitudinal 8-in. riveted steel pipe with 6-in. Y-branches. After the invert was placed, the steel arch ribs and the steel shingle plates were erected on it. The dry packing and the placing of the concrete were carried on without any difficulty. Wherever there was a heavy flow from the rock a hole was drilled back into that seam, and a deep-seated pipe was caulked back into this hole so that any water under pressure might be led readily through the lining and allowed to flow freely during the lining process and during the grouting of the space outside of the shell.

The space to be grouted in the dry packing was very large, averaging about 18-in. in diameter, with a radius of about 11 ft. The speaker

Mr. Hogan. does not remember how much grout was used in that shell, but perhaps Mr. Freeman will supply that information.*

After the lining had been placed and the water led through it by means of these deep-seated pipes, or allowed to drain through the dry packing down into the steel pipe in the invert, there were really two stages to the process of grouting—filling the dry packing, and shutting off the water. The object was to have a still lake of water into which the grout could be forced under low pressure. The grouting went on for six days; and so carefully was the high-pressure water controlled through the deep-seated grout pipes that there was no flow whatsoever in this lake of water in the dry packing.

In other cases, as much sand as possible was used in grouting the large spaces because it was less subject to churning action of the air, because it made a stronger grout and because the shrinkage was less. In general, unless grouting small seams, it is advisable to use as much sand as the mix will carry. The amount is entirely a question of experiment, but, in general, about half sand and half cement can be used. In this case, however, for various reasons, no sand was used; but it is believed that an equally good and more economical result could have been obtained by using sand with the cement.

The grouting was done from the bottom up, so that the grout was forced in with at least a 1-ft. head of grout over the inlet pipe. If the grout had been put in at the top and allowed to settle through the water, the cement would have been washed so that its setting would have been greatly retarded, if not entirely prevented. After the grout in the dry packing had set, the deep-seated pipes and the pipes in the invert were grouted under high pressure and the inward leakage reduced from more than 1 000 gal. per min. to less than 2 gal. per min.

In all these operations it was necessary, as has already been mentioned, to avoid excess of air and the blowing of air through the grout. In connection with other operations in the Rondout Tunnel, grout was cut out and was found to be very strong and dense, though somewhat stratified. There was not much separation of the sand from the cement, and the strength of some of the samples cut out was as high as 118 lb. per sq. in., compared to about 145 lb. for concrete.

Certain breaks in the lining of the tunnel were repaired by means of a steel shell made with 15-in. channels. As Mr. White says, the breaks were due to adjustment in the rock. There has always been a question in the mind of the speaker whether a number of those breaks could not have been repaired by grouting operations alone, without using the steel shell. However, it might have been necessary to put the tunnel

* Mr. Freeman stated that the total quantity of neat cement injected into the dry-packed section on the incline north of Shaft No. 4, Rondout Siphon, was 7 693 bags. As many as 1 200 bags were injected in one 8-hour shift.

under pressure several times and grout it several times in order to accomplish that purpose. The uncertainty of this procedure was too great, because it appeared at that time that possibly the work in question might be a limiting factor in the use of the Catskill Aqueduct. Mr. Hogan.

It would be interesting if some one familiar with the actual grouting operations could discuss the relative value of air-mixing and hand-mixing grout machines, and their respective uses. It is certain that there is a field for each. The Catskill Aqueduct was largely grouted by use of the air-mixing grout machine. However, in the Hudson River Tunnel, where the pressures were about 700 lb., per sq. in., ordinary plunger pumps were used with a suitable hand-mixing device attached. There are objections to the use of air-mixing grouting machines. The greatest objection, of course, is the quantity of air forced in with the charge, and the difficulty of getting rid of it.

The portion of the paper in regard to the grouting of the foundations of the Kensico and Ashokan Dams, and particularly the grouting of the foundations of the earth dikes, has introduced very interesting possibilities of improving the foundations of dams which have been constructed, and of which the foundations have proved to be faulty or are known to be faulty.

It did not seem to the speaker that the necessity for the high-pressure grouting is clear. The majority of the work was done at between 30- and 60-lb. pressure, and during this period the ground-water was allowed to flow through certain pipes to prevent the building up of back pressure. However, when it came to finally closing up a stretch, the active ground-water pressure in that stretch was often as high as 150 or 250 lb. per sq. in.; indeed, in the case of the Hudson River Siphon, it was as high as 500 lb. It was surprising how quickly that pressure built up the moment the pipes were closed, and it was to overcome this ground-water pressure that high-pressure grouting was necessary.

Francis Donaldson,* Esq.—The speaker was with three of the Aqueduct contractors and has actually placed a lot of grout. Mr. Hogan stated, and Mr. White agreed with him, that grout did not have much to do with making a tunnel tight, but the speaker begs to differ. Mr. Donaldson.

The speaker worked on one job not many miles from New York City. It was dry rock, the concrete lining was excellent, and when it was finished and looked as dry as possible, it was not quite dry enough for the engineers, so that high-pressure grouting was required. For weeks and weeks a gang of men went up and down that tunnel with step ladders and jack-hammer drills plugging at every drop of water; wherever the least dripping from the roof occurred a hole was driven and grout pumped into it. When we got through with that tunnel, it was positively dusty.

* New York City.

Mr. Donaldson.

The speaker was on several of the other jobs that the authors refer to and describe so well. In the Hudson Tunnel, we used grout at a higher pressure than was stated; this was necessary because the head outside the tunnel was 1 100 ft. and we had to force the water into the seams around the tunnel back into the crevices through which it came. It went back a good deal harder than it came in. We used a booster compressor up to the limit of our air pressures, and as we could not get enough pressure this way we pumped in water on top of the grout with a high-pressure Cameron pump. The pressure ran up to something like 1 000 lb. per sq. in., and broke out big chunks of the lining; it was good concrete, too, notwithstanding the authors' suggestion that it was a little weak in spots. We finally got the tunnel pretty tight.

At Shaft 4 on the City Tunnel (which was referred to in the paper, although it has not been discussed by any of the speakers), we drilled into a seam of sand. This sand bed was cut by one of the sump holes and a strong stream of water came up through the hole, carrying with it sand in good-sized grains. We plugged it with a tapered wooden plug, and then, because the stream had amounted to some 200 gal. per min., we decided to grout it. Having made this decision, we kept grouting this seam for about one month, but found that the sand prevented the grout from flowing into any of the holes in any considerable quantity. However, as soon as one hole refused we drilled another and kept drilling and grouting until the shaft bottom looked like a colander. There must have been several hundred holes in it.

When we could not get any more grout in we went on sinking and passed through the sand seam without much difficulty. We found that, although the grout had not permeated the sand, it had compacted it so that it resembled soft sandstone and all through the seam we found balls of grout ranging from the size of a man's fist to the size of his head. The leakage into the shaft, which came in through one hole—we did not know how much it would have amounted to if additional holes had been drilled—was cut from 200 to 20 or 30 gal. per min. This shows that grout can be used in sand under certain conditions; but no matter how thin it may be, grout will not permeate sand.

This discussion brings to mind two shafts that the speaker sank in West Virginia before he became connected with the Aqueduct work. The shafts were each about 275 ft. deep and it took two years to sink them. We had to pump about 2 500 gal. per min. and it required nearly 1 000 boiler h. p. all the time. The rock seams were open, and if we had known enough to grout them we could have saved much money and time.

When the shaft reached the seam through which the main flow came in, we found that it carried with it fine coke. Evidently the particles floated into crevices in the rock in the banks of the river farther up

stream, because still farther up the river there were a great many coke ovens, and after every heavy rain coke would be washed in. The biggest seam in the shaft was horizontal; it must have been 4 or 5 in. wide and ran nearly full of water. Mr. Donaldson.

One evening, going over to the shaft—something had happened to the pumps—the speaker met a darky coming away. He was carrying a good-sized catfish. The writer said, "Sam, where did you get that fish?" And the darky replied, "Lord, boss, that came through the big crack in the shaft".

WALDO C. BRIGGS,* M. AM. SOC. C. E.—The speaker's experience with grouting is confined to a soft ground tunnel which is a part of the Dual Subway System located under Flatbush Avenue, Brooklyn, extending from Prospect Park Plaza to Empire Boulevard. This section is a twin tunnel constructed in a single excavation, about one-half having been driven by means of a shield and the other half by a timber method. Mr Briggs.

With respect to stopping leaks, three different conditions were presented. Where the shield was started, the material penetrated was a clay carrying a great deal of water. The grouting operations were initiated in this section, and it was the intention to force in only sufficient grout to fill the void caused by the shell of the shield. The concrete behind the shield was placed in rings 31 in. wide by a pneumatic process. The concrete, due to the large amount of water in the soil, was porous; this condition, together with the large number of construction joints, produced a very wet tunnel. The result of the attempt to just fill the voids caused by the shell of the shield by means of the grout, so far as stopping leaks is concerned, was a complete failure.

A year or more after this section of tunnel had been completed and the grouting done as described, another attempt was made to stop the leaks by grouting. New holes were drilled through the lining just below the springing line through which grout was forced freely. For a certain distance the tunnel was made dry; but, inasmuch as grout is costly, a limit was set as to the amount of grout used, with the result that where the grouting was so limited, the tunnel is wet. The conclusion to be drawn from this is that porous concrete and construction joints in tunnel lining can be made water tight by grouting, provided sufficient grout and pressure are used. In the case in question the pressure used was 80 lb. per sq. in.

Another condition, where the shield passed through what was evidently a terminal moraine, the material excavated consisted of boulders and gravel entirely free from any matrix. A section of tunnel at this point, about 100 ft. long, was also wet after the lining had been completed; and, although grout was used freely, the leaks were not entirely

* New York City.

Mr. Briggs. stopped, probably due to the fact that the voids in the formation were so extensive it was impossible to force the grout into the concrete.

The third condition was where the timber method of tunneling was followed and where the material penetrated was clean, sharp sand carrying a large amount of water, the water again causing a somewhat porous concrete and a wet tunnel. Grout forced in through pipes located in the crown of each arch under a pressure of about 65 lb. cut off all water and left a bone-dry tunnel.

The speaker requested the foreman, Mr. Joseph Callahan, who had been in charge of the grouting operations on the work in question, to give him any information which experience had taught would be useful. The following notes were offered in response to this request:

"It is very important to have good hose and valves. The valves used should be cleaned thoroughly every morning or they will become clogged with grout and be useless. The hose and grout kettle should be washed out noon and night. A blow-off valve should be provided at the end of the hose so that if the grout gets blocked in the hose, it can be released. Only cement free from lumps and finely screened sand should be used. Coarse sand and lumpy cement will block the kettle and the hose and valves. When connections are made ready for grouting, try the air to see whether the hole is free. If the air passes slowly, try a thin batch with neat cement at high pressure. The grout pipe in the wall should be cleaned out with a rod. If a hole has been taking grout freely and stops suddenly, it indicates a block; perhaps a stone has fallen into the grout pipe. In such a case, let the grout come back into the kettle, close the valve at the wall and open the exhaust valve; this should take stones with it.

"All grout pipes should be cleaned at least 75 ft. ahead of the connection in order to release any water which may be behind the wall. As the grout shows ahead of the connection, plug the pipes with wooden plugs. When a hole is not finished at the end of a shift, blow in a little water; this will often keep the hole open until the next shift.

"Before connecting the air pipe to the kettle, blow air through pipe for dirt in the pipe will clog the valves in the kettle and cause trouble.

"Be sure that valves are screwed on tight and that there are no kinks in the hose. If a valve blows off or a hose 'busts', some one is liable to get hurt."

Mr. Sackett A. J. Sackett,* Assoc. M. Am. Soc. C. E.—The speaker can add very little to this excellent paper, which covers the ground so thoroughly. Mr. Hogan in the course of his discussion brought out the fact that it is impossible to force grout into poor concrete. The speaker has found that this is true except when the concrete is placed in compressed air, in which case grout washed on the surface of the concrete will be carried through the concrete and fill up the voids thus preventing the escape of air from the tunnel and also decreasing the leakage into

* New York City.

the tunnel when the pressure is removed. Experience gained from grouting the Moodna Siphon where 1½-in. pipes were used through the concrete lining shows that much better results can be obtained by using a larger pipe; 2-in. pipes were used on Section No. 63 of the City Tunnel, resulting in a better job of grouting and economy in time. Mr. Sackett.

When electric power is available, it is more economical to develop the compressed air by means of a small portable compressor at the grout tank than to transport the compressed air from a central plant through pipe lines.

In answer to the question as to why hand pumps were used in grouting on the Catskill Aqueduct, it has been the speaker's experience that grouting by hand pumps is a makeshift and only resorted to on small jobs and at places where power is not available or too expensive to obtain.

Concreting the 150-ft. forms on Section No. 63, which Mr. Sanborn has requested the speaker to describe, was a simple process and did not differ in any material way from the methods used to line the tunnel on other sections of the aqueduct. Sand and crushed stone passed by gravity from bins at the shaft head to a measuring hopper, then through a 12-in. wrought-iron pipe to a 1-cu. yd. concrete mixer mounted at the foot of the shaft. The cement was mixed with water at the top of the shaft, to prevent dust, and dropped though the same pipe with the coarse aggregate. The mixed concrete was transported in 1-cu. yd., side-dump cars, in trains of 8 to 10 cars hauled by electric motors. The forms were built of steel and mounted on trucks which traveled on the same track used by the material cars. The trains of concrete cars were hauled up an incline to the platform of the forms by an electric hoist. The side-wall form traveled in front of the arch form, the two being concreted at the same time. Cars were dumped on the platform, which was about 18 in. above the springing line of the tunnel, and the concrete was shoveled into the forms by hand.

Andrew A. Cohill,* M. Am. Soc. C. E. (by letter).†—In the construction of two tunnels under the East River at 60th Street, known as Route 61, Broadway-Fourth Avenue Subway, there were conditions to contend with that were exceptional, especially the leakage. There was a water pressure exceeding 50 lb. per sq. in. The problem of taking care of the water under Blackwell's Island was a difficult one. Mr. Cohill.

With C. M. Holland, M. Am. Soc. C. E., as Tunnel Engineer, and M. H. Freeman, M. Am. Soc. C. E., as Resident Engineer in direct supervision of the work, precisely the same methods as those described in this paper were used, and the results obtained were excellent. Approximately 11 000 ft. of tunnel was grouted, of which 5 000 ft. has a

* New York City.

† Received by the Secretary, February 5th, 1920.

Mr. Cohill. cast-iron lining. The leakage before grouting was 800 to 900 gal. per min.; this was reduced, by grouting, to approximately 25 gal. per min.

The writer wishes to compliment the authors on the excellence of this interesting and valuable paper.

Mr. Mayell. A. J. Mayell, Assoc. M. Am. Soc. C. E.* (by letter).†—The writer was much interested in the grouting methods used on the water tunnels, as described by the authors, and especially in the use of grout of varying consistencies, and can testify that the methods are efficacious in stopping leaks not only in water tunnels but in the New York subways.

Similar methods were recently used with great success by M. H. Freeman, M. Am. Soc. C. E., at the Broadway Station of the Canal Street Crosstown branch of the Broadway-Fourth Avenue Subway where considerable leakage developed after construction was completed, and ground-water which had been lowered by pumping during construction regained its original elevation.

This station is entirely below mean high water, and was therefore enveloped in water-proofing consisting of two layers of brick laid in asphalt mastic. Where it passed under the Interborough Subway in Lafayette Street and the Centre Street Loop in Centre Street, the water-proofing, instead of being carried over the roof of the new structure, was lapped on to the water-proofing on the under side of the overhead structures. It is probable that a slight subsidence of the mastic together with pressure from the water head caused this water-proofing lap to open slightly and admit ground-water into the subway.

Before the ground-water had risen to its normal level, the station finish was placed and the subway put in operation, so that when the leakage developed the water was carried by the hollow tile and through air spaces a considerable distance from the points of entry and flowed across the platforms causing annoyance and inconvenience to passengers.

It was decided to attempt to stop the leaks by grouting from the inside of the structure; holes were drilled through the interior walls in the general direction of the water-proofing lap, and grout was injected under pressures of from 30 to 70 lb. per sq. in. The total leakage at the start was about 160 gal. per min., most of it coming in under the two overhead structures. The grouting reduced the leakage to less than 1 gal. per min.

The grouting was done under difficult conditions. The station platforms and passageways from which grouting operations had to be carried on were crowded during rush hours and great care had to be taken to prevent accidents. Moreover, special precautions were necessary and constant vigilance had to be exercised to prevent the grout from filling

* New York City.

† Received by the Secretary February 4th, 1920.

the hollow tile, air spaces, lighting conduits and drains. Pressures had to be kept fairly low to prevent damage to the structure and to the overhead structures. Mr. Mayell.

The great force that may be exerted by grout under pressure is indicated by the fact that the Interborough Subway, which during the construction of the structure below it had settled from 1 to 3 in., was raised from 1 to $1\frac{1}{2}$ in. by the grouting. This occurred after all the holes under the Interborough Subway had been grouted and the process of "squeezing" to complete the seal was in operation. The squeezing was done by a hand grout pump with a pressure gauge attached. The pressure generally used was between 50 and 60 lb. per sq. in., but on this occasion the grout was going in very slowly and the pressure was increased, as it was thought that the space between the two structures had been quite thoroughly grouted and that the grout could not exert pressure on any great area of the overhead subway bottom.

No damage was done to the overhead structure; on the contrary, the lifting eliminated the greater part of the depression in the inverts of the Interborough structure which the operating company had thought might affect the drainage of its tracks.

That the results obtained were so successful was due to the intimate knowledge which Mr. Freeman had of the action and effect of grout of different consistencies and his constant attention to this detail.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE "LIGHT RAILWAYS" OF THE BATTLE FRONT IN FRANCE

Discussion*

By Messrs. William Wren Hay, F. W. Green, William M. Black, and William J. Wilgus.

William Wren Hay,† Assoc. M. Am. Soc. C. E. (by letter).‡—It is not generally realized that the so-called "Light Railway" was carefully studied, and the standards of track and rolling equipment developed in Europe during the late '80s. Originally used by Decauville in his plant at Petit-Bourg, it was proposed by Col. Pechot (then a Captain of Artillery), as a means for the movement and supply of heavy siege artillery, and was the object of extended experiments and studies conducted by Col. Pechot, with the collaboration of M. Bourdon, a Government engineer, during the period 1881-89. The name "Pechot" survives in the Pechot locomotive, Type 1888, in the system of multiple axle trucks used under heavy artillery pieces, and in various manufacturers' catalogues in the track described as "System Pechot." Mr. Hay.

In 1882-85, the track now known throughout the world as "Decauville" was developed by the company of that name and has served as the model for most of the track made in Europe, and its influence is readily traced in the United States. The system developed in France served also as a model for the Germans, and after tests conducted by them in 1891, was adopted in 1892, and standardized as Army equipment in 1897.§ There is a record that as early as 1879 the Austrians had some

* This discussion (of the paper by Frank G. Jonah, M. Am. Soc. C. E., published in January, 1920, *Proceedings*, and presented at the meeting of March 3d, 1920), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Forest Hills, N. Y.

‡ Received by the Secretary, February 18th, 1920.

§ *Le Genie Civil*, Vol. 72, p. 449 (June 22d, 1918).

Mr. Hay. narrow gauge railway equipment for military purposes, but the writer is unable to determine when it was standardized for such use.

The Germans adopted the light railway for strategic use in times of peace, supplementing their standard gauge railways toward their frontiers, but after trench warfare became fixed in the recent conflict, they developed a very dense system of narrow-gauge supply lines, particularly in front of Verdun and in the St. Mihiel salient, as is well shown on the map (Plate I). So general was their use in the St. Mihiel area, that batteries and billeting areas on the slopes of steep hills were supplied direct from the main lines in the valleys by means of funicular tracks.

Originally, the writer believes, the French Army developed this material for use in connection with siege batteries and permanent fortifications, but it was soon realized that it was also of strategic, or tactical, value, and considerable experience was gained by them in connection with the military railways built in the French Zone, in Morocco. From press reports, the French had at the beginning of the war about 870 miles of 60-cm. track, with 60 locomotives, and 350 cars. At the signing of the Armistice, this had been increased to almost 2 500 miles of track, 900 locomotives, and 4 500 cars. The American forces were reported by the Chief of Engineers to have been operating 1 390 miles of track, of which about 1 080 were captured German lines, 165 locomotives of all classes, and 1 695 cars. The writer has seen no statement of the mileage of either the British or German lines.

Contrary to the text, both the French and German standards for portable track are for rail weighing 9.5 kg. per m. (about 19 lb. per yd.), in both cases attached to eight rolled steel ties per 5-m. length, the German track being clip-bolted as shown, the French cold riveted to the ties. The usual French rail has a greater base than height, while the German rail has a greater height than base. During the war, many sections were in use. These can be compared with the equal base by height standard 20-lb. rail used by the English, and the standard American 25-lb. section. The axle concentration on this track was not allowed to exceed 3 500 kg. for 0-6-0 type locomotive loading. (In this connection, the conclusion reached by British engineers in India was to allow 3 long tons—about 3 000 kg.—for the concentration on 20-lb. rails, 24-in. gauge track).

The Pechot locomotive has received a great deal of publicity since the opening of hostilities in 1914. It was originally developed for use in and around fortifications, where sharp curves and steep grades were necessary, and probably rendered its most notable service on the steep hillsides in and around Verdun, the very service for which it was intended. The trucks are of the suspended, articulated type. The firebox is double, with a single grate, and so designed that for all grades

less than 10% it is constantly submerged. The interesting thing to the general public is that this locomotive is double and "works both ways". The grate area is too small for heavy service. These locomotives are very expensive compared to other types. Mr. Hay.

A locomotive of the Mallet articulated type, 0-6-6-0, was built in Europe before the War and received some use in Morocco and on fortification construction, but whether any was used on the light railways of the battle front the writer never heard. The majority of the locomotives used by the French were the Decauville 8-ton (empty), 0-6-0 type, developed from the experience gained in Morocco.

F. W. Green,* M. Am. Soc. C. E. (by letter).†—The author is to be congratulated on the thorough and comprehensive manner in which he has treated this interesting subject. While much has been written on various other activities incident to the conduct of the war, very little has been done in the way of description of the construction and operation of the "light railways." This paper, therefore, presents to the Profession a subject comparatively new; and while it relates to the application of the light-railway principle to military operations, the civil engineer will not fail to observe its availability for a number of purposes, in which it may prove to be more economical than practices heretofore followed. Mr. Green.

While serving with the Third British Army as an officer of the Twelfth Engineers, in an endeavor to discover the *raison d'être* of the "light railways", the writer was informed that the experiences of the winters of 1914-15 and 1916-17, especially the latter, clearly indicated the danger of military reverses involved in an adherence to the use of motor lorries for transportation between railheads and battle front. With the unprecedented density of men in the battle lines, transportation by motor transport involved chronic congestion, with consequent decrease in mobility, as well as the diversion from combat duty of large numbers of men required to keep the highways passable. It was felt that the saturation point had about been reached when the damage done to roads by motor trucks hauling road repair material almost offset the benefits accruing to the road by the use of said material.

In casting about for means of ameliorating these conditions, their attention was called to what the French styled the "Decauville" railway, usually of 1-m. gauge. The British decided to adopt a gauge of 60 cm. because of considerations of greater mobility, less cost, and inability of the enemy to connect up with it and use it in case of retirement before it could be removed.

The writer recalls having observed the use of light railways in certain large manufacturing plants, notably steel mills, as long ago as 25

* St. Louis, Mo.

† Received by the Secretary, February 19th, 1920.

Mr. Green. years. It is not known whether that was another application of the "Decauville" principle, or a mere coincidence.

Early in 1917, light railways were started experimentally behind one of the British Armies. Their success was so immediate that by the summer of that year the larger percentage of transport between broad-gauge rail-heads and the battle front was changed from motor lorries to the light railways. The writer was informed by a British officer that about 18 miles of single track light railway operation in the Gouzeaucourt sector permitted the abandonment of the operation of over 600 motor lorries and the retirement from road maintenance labor forces of over 3 000 men.

In the back areas, steam locomotives were used; where under enemy observation day and night, gas or gas-electric tractors were employed. In the design of the steam locomotives, the saddle type of water tank was provided, presumably because of the additional adhesion available for tractive effort. Whatever advantage thus accrued was, in the writer's opinion, more than offset by the decreased stability against overturning resulting therefrom. As these locomotives were "shopped", the saddle tanks were sometimes removed and mounted on a trailer type of tender behind the locomotive, and it was remarked that the tendency to derailment was very much reduced.

It is believed that there is a large field for the development of this type of transportation in the United States. A great amount of highway construction is now under way in many States. The transport of road material from broad-gauge railway cars to the point required on the work by gas or gas-electric tractors and self-dumping equipment should prove much more economical than by the use of teams. Similarly, there are large areas of hardwood timber suitable for railway cross-ties and other purposes, which heretofore have been considered beyond the limit of commercial exploitation. The light railway, cheap of construction and maintenance, the track of which can be used over and over again with small cost of removal, ought to find a field for development in such cases.

The author undoubtedly gave much more thorough consideration to developing his design for the rail-head at Sorcy than is usual under war-time conditions. As a result he has succeeded in obtaining the most complete and practicable layout the writer has ever seen. In the stress of war it is quite common for such layouts to be made to fit the ground with a minimum of construction effort, without regard to convenience and facility of operation.

In the design of the lift bridge at Void, the author has demonstrated not only the resourcefulness with which American civil engineers applied themselves to the solution of military problems, but also that Mars and Apollo follow different paths.

The Howe trusses over the Eastern Railway at Sorcy, however, are evidently the result of very careful and conscientious designing, and when considered from the standpoint of military engineering, are unusually pleasing to the eye. The location of the line from Abainville to Sorcy also shows that much thought and study was given to it, and Col. Jonah is entitled to much credit for the successful results obtained. Mr. Green.

WILLIAM M. BLACK,* M. AM. SOC. C. E. (by letter).†—In the introduction to his paper, the author states that the execution of the light railway work was almost entirely in charge of Engineers from civil life. At this time when the necessity for universal military training for our citizens is under consideration, and further, while some members of the Society are advocating the removal from the charge of the Corps of Engineers of the Army of the civil works from which alone the officers of that corps were enabled to obtain practical training in time of peace in the organization and conduct of important engineering works—with the development of character which results from such responsibilities—certain comments on this statement are pertinent. Mr. Black.

At the outbreak of the war, in accordance with the traditional policy of our country, the United States had available a pitifully small number of trained soldiers by whom her great man power could be trained and made useful for the struggle into which she had been forced.

On April 10th, 1917, there were only 256 engineer officers in the Regular Army. In the National Guard, the Engineer Service had been neglected and even in the few engineer units of that service many of the officers were not engineers. During the war the number of regular officers was increased to 449, partly from graduates of the United States Military Academy and partly from young graduates of civil technical schools. Of these regular officers, 94% were engaged in military duty during the war. Of the remainder, the majority were physically unfit for field work. They, assisted by engineer officers on the retired list and the United States Assistant Engineers, kept the civil works in charge of the Corps in uninterrupted operation. At the outbreak of the war, the total enlisted strength of the Engineers of the regular army was 2 228, organized into 15 units. The necessities of war required the expansion of the above to 473 units, comprising 284 983 men. The number of commissioned officers was increased to 10 886.

It is manifest that this great expansion could not have been accomplished efficiently without the aid of the civil engineers of the country. This aid was rendered promptly and willingly, and the final success of our operations in France is manifestly due greatly to their efforts. But is there a man of all this number who did not regret that he had not had previous training, at least in matters of army organization and

* New York City.

† Received by the Secretary, February 26th, 1920.

Mr. Black. administration? Was it not a difficult task for many to merge their individualities in the whole and to learn to act simply as one cog of the great military machine? Is there one who did not recognize the waste of life and treasure which follows the entering of a nation into war without proper preparation and prior training of her man power?

The author has given an interesting account of one item of the light railway work of our forces in France. Before we entered into the war the necessity for light railways had been established as an essential part of the Army transportation system. Its zone of operations is from the rail head beyond which the standard-gauge railways cannot be maintained, up to the firing line, a distance of about 10 miles ordinarily, although in the Toul sector there was a regular service over a distance of from 26 to 33 miles. When hostilities ended 2 240 km. of light railways were under American Army control, of which about 300 had been originally constructed by the French, but rehabilitated by the Americans, 200 had been constructed outright by the American forces and 1 740 had been captured from the Germans.

Up to February 1st, 1919, American-operated light railways hauled 860 600 tons of ammunition, forage, rations, water and construction materials and personnel, representing a ton mileage of 8 106 700, including the empty haulage.*

Though the material supplied, both track and rolling stock, proved satisfactory, there is need for further experiment and improvement. In some respects the German locomotives were judged superior to ours.

As a measure of economy in administration as well as to provide a means for trying out new devices in material and for giving training to a limited number of officers and enlisted men, the writer, when Chief of Engineers, advocated the installation of a system of light railways at each of the large permanent army camps. Such a system is installed at the Engineer Post at Camp A. A. Humphreys, Va., and its operation has resulted in a material saving of expense as compared with the usual transportation of men and supplies by motor trucks.

Mr. Wilgus. WILLIAM J. WILGUS,† M. AM. SOC. C. E. (by letter).‡—The writer feels that it will not be amiss to touch on the early development of the Light Railway Section of the American Army's transportation activities in France. In June, 1917, as a member of a commission sent by the War Department to report on the railway needs of the armies of the Allies, the writer had an opportunity of cursorily observing the methods adopted by the British and French on the Western Front; and shortly after, when he was assigned to duty with Gen. Pershing's staff and undertook the task of planning for the transportation of our troops and supplies, he was able to use the information so gained as a basis

* Historical Report, Chief Engineer, A. E. F.

† New York City.

‡ Received by the Secretary, March 2d, 1920.

for estimating our probable requirements in that respect, including "Light Railways". Mr. Wilgus.

In the absence of a decision as to the intended size of the American forces in France and where they were to fight, the writer arbitrarily assumed that within a year they would total 500 000 fighting men, equivalent to, say 750 000 men in all branches of the service. Likewise he assumed that the combat troops would function in the foothills of the Vosges, along a front of some 40 miles centering on Nancy, and that the volume of supplies of all kinds to be transported would average 60 lb. per man per day for all our forces, or 30 lb. per man per day in the advance area for those actively engaged at the front. It should be added that a 40-mile sector was assumed because it was understood that an average of 12 500 troops per mile of front was the maximum that could be effectively employed. Later, it was found that this average was too small and that the point of saturation was somewhere between 15 000 and 17 500 per mile.

A depth of from 5 to 12 miles along the front was taken as the zone within which supplies would be distributed largely by means of light railways, as experience had shown that it was unwise, from the standpoint of safety, to maintain standard-gauge rail-heads nearer than the lesser of these distances, while operating conditions forbade a distance in excess of the greater. The later experiences of the British led them to the conclusion that the light railways could function with the rail-head at a minimum distance of 8 miles from the front with nearly the same operating efficiency as at 5 miles, while the safety would be quadrupled. In fact, they considered, as a result of several years of trench warfare, that the depth of the zone to be served by light railways should vary from 8 to 16 miles, instead of 5 to 12 miles, the accepted practice at the time of our entry into the war.

Within this zone it was customary, in general, to have three single-track lines, parallel with the front, and connected with each other and with the standard-gauge rail-heads in such manner that the traffic of the group serving each rail-head would circulate in one direction over a multiplicity of routes, with ample insurance against serious interruption in case any part of the group should be injured by shell fire. The line nearest the enemy was intended for supplying the front line trenches and light artillery, the second for the medium and the third or rear line for the heavy guns. The standard-gauge rail-heads, at which supplies and troops were transferred to the light railways, averaged a distance of 3 miles apart in the French sectors, each rail-head thus serving approximately 22.5 route miles or 30 single-track miles of light railways, which in turn distributed supplies for from 40 000 to 50 000 men.

On the basis of an average of 10 miles of single track, or 7.5 miles of route, per mile of front, it was estimated that materials should be

Mr. Wilgus. ordered for 400 miles of single track, with steel ties (2 640 per mile), to which 20% was added for various services in the rear and for stock on hand, a total of 480 miles.

The requirements for turn-outs were found to average 10 per mile of single track, and therefore 4 800 sets were ordered, of which one-half each were to be right and left handed. It was designated that the leads should have a radius of 30 m. and that the ground switch-stands should throw parallel to the track.

As stated by the author, rails weighing approximately 20 lb. per yd. were in general use by the Allies, but there was a general feeling, especially among the British, that this was too light for the proper maintenance of track, ballasted as a rule with poor material and laid on soft ground often torn by shell fire. Under these circumstances a stiffer rail weighing 25 lb. per yd. was adopted, even though the heavier weight would be more disadvantageous in laying track. Lengths of rail were fixed at 5 m. with a small proportion of 2½ and 1¼-m. lengths for closures at curves; 20% of the rail was ordered curved, of which 70% was to have a radius of 30 m., 15% of 50 m., 7½% of 20 m., and 7½% of 100 m.

The question of ties was troublesome. The operations of the British lay in the flatter region of the North, where the soil was comparatively soft and where the topography was such as to require cuts and fills; whereas with the French in the higher altitudes rock was at the surface and the terrain was such that tracks could be built on the contour lines with practically no grading. In consequence, the British in many places found necessary the use of such wood as they could pick up for interlacing between the steel ties, especially in shell-torn areas where it was necessary to raft the track over soft fillings. It was felt that the troubles of the British would be obviated by adopting short wooden ties, 4 by 6 in. by 4 ft., of which 115 000 were ordered specially for that purpose.

The type of fastenings called for careful consideration. The British did not look with favor on the French practice of riveting the ties to the rails because: (*a*) much trouble resulted from irregularity of the fixed gauge due to poor workmanship; (*b*) the rivets were said to rust and break under traffic, with resultant derailments; and (*c*) pre-assembling of the track parts prevented close packing for shipment and in consequence was wasteful of vessel and car space in transportation by sea and land. The latter reason, bearing as it did on the transportation factor that was to have so much to do with winning the war, was considered sufficiently forceful to dictate the use of clip fastenings which permitted the close packing of the rails and ties separately, and later their assembling when and where needed.

In the ordering of rolling stock the experience of the British was found to be borne out quite closely by an analysis of the requirements under the above-mentioned conditions.

Counting three gasoline as equal to one steam locomotive, the calculated needs, based on an average length of haul of $5\frac{1}{2}$ miles, an average daily performance per equivalent working locomotive of 300 ton-miles and a surplus of 40% over actual working needs, were about 0.54 equivalent locomotives per mile of single track or a total of 258. Of these approximately three-quarters, or 195, were to be steam locomotives. The remainder, multiplied by three, gave the required number of gasoline engines, 189, of which two-thirds were to have a capacity of 40 h.p. and one-third of 20 h.p. It was requested of the War Department that the steam locomotives weigh $3\frac{1}{2}$ tons per axle and that the saddle tanks be so hung as to give a low center of gravity. The failure to observe this precaution with the British was the cause of frequent and embarrassing derailments on soft track. Mr. Wilgus.

As to cars, the British authorities gave their average requirements as ranging from 12 to 14 per route mile or 9 to $10\frac{1}{2}$ per track-mile. Calculations based on the aforesaid data and on a daily performance of 27 ton-miles per working unit, and an allowance of 30% in excess of average working needs, yield a figure of 8.2 cars per route mile. Owing to uncertainty on this point at the time of estimating in July, 1917, a figure was used of approximately 9.3 cars per route mile or 13 per equivalent locomotive, making the total number ordered 3 332, of the following types:

17-ft. bogie cars, open top, low sides.............	1 700
17-ft. bogie flats, with stanchions................	480
8-ft. box cars..................................	720
Bogie bolster	96
Tip cars	240
Bogie tank cars (1 500 gal. for army use)........	96
	3 332

It was requested that the cars having a capacity of 9.3 long tons should have their contents capacity increased from 225 to 240 cu. ft., equivalent to the contents of the 10-ton standard gauge car of the European type, as practice had shown that this was highly desirable in transhipping ammunition at the railheads.

The cabled order, sent in July, 1917, also included 220 crossing-frogs of various angles, for intersecting standard-gauge and light-railway tracks; a selector telephone system for 330 miles of territory, with five dispatchers' outfits and station apparatus on the basis of stations one mile apart; 330 portable cabins; 48 portable gasoline pumps including suction pipes and fixtures, each with a capacity of 3 000 gal. per hour against a head of 150 ft.; 48 000 lin. ft. of various sized pipe with valves and fittings; 48 demountable 15 000-gal. water tanks with valves and spouts; tools and machinery for a general repair shop and

Mr. Wilgus.

for 16 round-houses; maintenance tools for 420 track gangs; 20 locomotive cranes; a supply of 8 by 16-in. bridge stringers, and ample spare parts.

At that early date the question of forces for constructing, maintaining and operating the light railway system was also considered. The experience of the British pointed to the following average needs per single track mile:

	Number of men.
Operation, exclusive of maintenance of way........	10
Maintenance of way................................	14
Total	24
Construction (maximum)	20
Grand total....................................	44

Therefore it was contemplated that upwards of 21 000 men would be required under these conditions.

In forecasting fuel consumption it was estimated that steam locomotives would require 48 lb. of coal per locomotive mile and gasoline locomotives 0.35 gal. per mile.

The writer's connection with the "Light Railways" section of the Army's transportation service was terminated a few months after its inception, and hence he was not intimately in touch with its later development. He ventures the hope that the author will point out the faults of the original plan and procedure as here outlined, not only as an aid to those who later may have to cope with similar problems, but also as a warning against the inexcusable laxity and absence of ordinary foresight on the part of the War Department or other Governmental agency in having done absolutely nothing, prior to our entry into the war, to study the transportation needs and practices of the contending armies through experienced eyes, with a view to having in readiness a well thought-out plan embracing suitable provision for the material and personnel necessary for the prompt disembarking, storage, and distribution of our troops and supplies from the sea to the firing line.

It is also to be hoped that the author, in addition to pointing out the way in which possible errors in our early planning of the "Light Railways" may be avoided in future military operations, will also dwell on the extent to which the change from trench to open warfare modified the forecasts which were predicated on the preservation of the *status quo*. At the time of our entry on the scene, the British considered that as far as any great advance was concerned, a forward movement of, for example, 5 to 8 miles in two days would mean "open warfare" in which event the use of light railways would disappear; but it was

of course unsafe not to order light railway materials on the theory that the Americans would be successful in immediately changing the character of operations. However, about the time our Army commenced to function on a large scale the enemy rapidly fell back on the entire Western front and this to a great extent relegated the light railways to the background. It will unquestionably be interesting and helpful to have known the extent to which this change in the military situation affected the usefulness of the means of distribution that had proven to be so indispensable while the armies were deadlocked. Mr. Wilgus.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

LINN MURDOCH HUNTINGTON, M. Am. Soc. C. E.*

DIED NOVEMBER 24TH, 1919.

Linn Murdoch Huntington was born on November 11th, 1884, at North Bend, Nebr., and was descended from old New England stock. He was graduated in Civil Engineering from the University of Nebraska in 1904, having spent all his vacations in railroad work.

After his graduation, Mr. Huntington went almost immediately to the Panama Canal and spent practically the remainder of his life in the tropics. During his three years in Panama, he rose rapidly from Rodman to Assistant Superintendent of Public Works and Assistant Engineer of Maintenance of the Panama Railroad. Transferred to Cuba during the Second Intervention, at the request of Governor Magoon, he became Second Engineer in the Department of Public Works and, later, was engaged in consulting work with Marx and Windsor, an American contracting firm.

Leaving Cuba in 1910 Mr. Huntington joined the Department of Public Works of the Dominican Republic, which he served most faithfully and creditably in many capacities until 1913, when nearly all the American employees were precipitately discharged from the service.

Shortly afterward, in 1914, he became Vice-President and General Manager of the Bramon Estates Company, which owned and operated one of the largest coffee plantations in Venezuela, where he remained until a few months before his death. It was while on this work that his wonderful persistence and splendid loyalty showed to its best advantage. For more than a year he stayed on, fighting an unequal battle for the retention of the property fraudulently taken over by German interests, though he received no salary and little support from his principals at home.

Mr. Huntington was a pre-eminent example of the fighting American engineer who has had such a strong influence in every land where the empire builder has followed the explorer into the out-of-the-way places of the earth. He might have been the inspiration of the "Soldier of Fortune" which has enticed so many of his kind to the land of the *dolce far niente*.

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* Memoir prepared by J. L. Mann, Esq.

"Hunt" was a typical "soldier", fighting and working incessantly, never quitting, neither stopping nor giving up till the job was done, whatever it might be. Obstacles added zest to the work, but he never dreamed of failure. At the end it was the same; though suffering from a disease of the throat which had prevented him from taking even water and having been kept alive for several days with oxygen, he gave no sign that he despaired of recovery. As far as any one could see, he considered that his prospects were of the brightest, and his plans were all for the future. He died on November 24th, 1919, and is survived by his widow and a son.

Having spent practically all his professional life in the tropics, Mr. Huntington had absorbed the atmosphere of the Latin American and spoke the language so well that he was frequently taken for a native of various South American countries.

He was a member of the National Arts and Salmagundi Clubs of New York City, and was the author of several short stories published by Harper's and other magazines.

Mr. Huntington was elected a Junior of the American Society of Civil Engineers on May 2d, 1905, an Associate Member on August 31st, 1909, and a Member on December 31st, 1913.

WILLIAM NEWBROUGH, M. Am. Soc. C. E.*

Died November 2d, 1919.

William Newbrough was born at Philadelphia, Pa., on December 15th, 1860. After receiving his preparatory training at Dr. Sach's School, he entered Columbia University, New York City, in 1876, and was graduated from the School of Mines in 1884 with the degree of E. M. He received his A. M. degree in 1885.

From 1884 to 1886, he was Instructor in Civil Engineering at Lafayette College, and from 1886 to 1888 acted as Instrumentman and Bridge Engineer with the Atchison, Topeka and Santa Fé Railroad.

During 1888-89, Mr. Newbrough served as Professor of Engineering in the State College of Kentucky, and for the two years following he was in private practice and also held a position as Computer in the United States Surveyor-General's Office, at Salt Lake City, Utah. He continued private practice in the latter city until 1900, including among his more important work, Contract 188 for the survey of the Public Lands of the United States in Utah, the duties of Chief Engineer of the Lucerne Land and Water Company, and the design, location,

*Memoir prepared from information on file at the Headquarters of the Society.

and construction of 14 miles of a canal crossing three divides and costing $23 000.

In 1892 Mr. Newbrough designed and located the Black's Fork and Twin Butte Canals at Fort Bridges, Wyo., which were enlarged, later, partly by himself. From 1894 to 1896 he was engaged on surveys, statistics, tracing coal veins and outcrops, general exploratory work, assessments, etc., for Mr. P. J. Quealy of Kemmerer, Wyo., in connection with the development of the Kemmerer coal deposits, and from 1896 to 1900, he was employed as Engineer for Quealy and Kemmerer and the Kemmerer Coal Company, having full charge of all engineering work. He also laid out the Town of Kemmerer and designed its water-works.

In 1900, Mr. Newbrough went to Detroit, Mich., as Acting Assistant Superintendent of the Penberthy Injector Company. In 1902, he returned to Evanston, Wyo., and immediately was engaged as Consulting Engineer by the Kemmerer Coal Company. In 1903 he was appointed Engineer of the Diamond Coal and Coke Company, Diamondville, Wyo., and from 1902 to 1904 acted as Engineer for Beckwith, Quinn, and Company, Evanston, Wyo.

In 1905, Mr. Newbrough engaged in private practice as a Civil and Mining Engineer with an office at Evanston, Wyo., until 1914, when he returned to Detroit, Mich., as General Superintendent of the Penberthy Injector Company. He remained with this Company until 1916, when he opened an office as a Consulting Engineer at Kemmerer, Wyo., which he continued until his death on November 2d, 1919.

Mr. Newbrough was married to Gertrude Sturtevant, of Brooklyn, N. Y., in January, 1897. She died in 1917. He is survived by a sister, Elizabeth Newbrough.

Mr. Newbrough was elected a Member of the American Society of Civil Engineers on April 6th, 1904.

JOHN PATRICK O'DONNELL, M. Am. Soc. C. E.*

Died December 2d, 1919.

John Patrick O'Donnell was born in Dublin, Ireland, on July 1st, 1859.

He was articled with Messrs. Stevens and Sons, Railway Signaling Engineers, of London and Glasgow, in 1875, and served with that firm until 1882, when he was appointed Assistant Signal Superintendent on the Lancashire and Yorkshire Railway.

* Memoir prepared by J. Groom, Esq.

From 1885 to 1889 Mr. O'Donnell was in the service of the London and South Western Railway, under Mr. Jacomb, Chief Engineer, and during this period he designed and carried out extensive alterations to the signaling system at Waterloo Station in London, and other works, for that company. Subsequently, he joined Mr. Dutton in establishing the firm of Dutton and Company, Railway Signaling Engineers, of London and Worcester, leaving the firm in 1894 to join the late Mr. A. G. Evans, in founding the firm of Evans, O'Donnell and Company, Railway Signal Works, Chippenham and London, which carried out many extensive signaling works in England and abroad. Evans, O'Donnell and Company subsequently amalgamated with Saxby and Farmer, Limited, and Mr. O'Donnell held the position of Joint Managing Director for a number of years.

In 1901 he formed the British Pneumatic Railway Signal Company, of which he was Chairman and Managing Director until his death. Mr. O'Donnell started the first works for the manufacture of pneumatic tools on a considerable scale in Great Britain, and was one of the pioneers of power signaling there. He installed the first automatic signals on main passenger lines, *viz.*, on the South Western Railway between Grateley and Andover, and subsequently between Woking and Basingstoke. The first power signals installed on passenger lines in Great Britain were put in at Grateley on the South Western Railway by Mr. O'Donnell who was, also, one of the earliest advocates of concentration sidings and hump shunting, and established the big installation at Wath on the Great Central Railway.

Extensive contracts were carried out under his direction on the Great Central Railway, the London and Southwestern Railway, and the Central Argentine Railway, etc. At Victoria Station (South Eastern and Chatham Railway) the latest form of signaling—three-position, all electric interlocking—was finished at the time of his death.

Mr. O'Donnell was the inventor of a large number of appliances for railway signaling and kindred subjects, and was always well to the fore in civil and mechanical engineering developments in connection with railways.

He was a Member of the following: Institution of Civil Engineers (Great Britain), Institution of Mechanical Engineers, Canadian Society of Civil Engineers, Railway Signal Association, and the Institution of Railway Signal Engineers. He was a Fellow of the Chartered Institute of Patent Agents.

At the time of his death Mr. O'Donnell held, among others, the following positions: Managing Director of the Superheater Corporation, Limited; Managing Director of the British Power Railway Signal Company, Limited; and Managing Director of the Economical Boiler Washing Company, Limited.

Mr. O'Donnell was elected a Member of the American Society of Civil Engineers on July 5th, 1893.

IRVING SPARROW WOOD, M. Am. Soc. C. E.*

Died October 20th, 1919.

Irving Sparrow Wood, born in Providence, R. I., on November 27th, 1857, was the son of Charles P. and Sarah S. (Robinson) Wood. He was of New England parentage. His education was obtained from the public schools of his native city, supplemented by a course in Mowry and Goff's English and Classical School, a local institution, from which he was graduated in June, 1877.

Mr. Wood promptly took up the line of work which he was destined to follow during his life, entering the office of the City Engineer of Providence and working there in various capacities until the spring of 1881, when he was assigned to the Water Department, then in charge of the late Edmund B. Weston, M. Am. Soc. C. E. He soon became First Assistant, acting as such until May 1st, 1899, when he was appointed to the vacancy caused by the resignation of Mr. Weston. This position he held until his death on October 20th, 1919, which occurred in the house in which he was born.

During the twenty years of his administration, the population supplied by the Providence Water-Works increased from about 180 000 to nearly 300 000, and the annual consumption of water rose from about 3 500 000 000 gal. to nearly 8 000 000 000 gal. This expansion required a corresponding increase of the distributing pipes year by year and the installation of more ample and efficient pumping machinery. An extensive and highly successful filtration system was also introduced.

Mr. Wood was affiliated with the Boston Society of Civil Engineers, the New England Water Works Association, and the Providence Engineering Society.

He was married on October 14th, 1903, to Miss Margaret E. Read, who survives him.

Modest and unassuming in demeanor, Mr. Wood was diligent and conscientious in the performance of his official duties, courteous and fair with his subordinates, agreeable as an associate, and faithful and considerate as a friend.

Mr. Wood was elected a Junior of the American Society of Engineers on March 5th, 1890, an Associate Member on March 7th, 1900, and a Member on March 6th, 1906.

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* Memoir prepared by Herbert E. Sherman, M. Am. Soc. C. E.

WILLIS BENTON WRIGHT, M. Am. Soc. C. E.*

DIED NOVEMBER 16TH, 1919.

Willis Benton Wright was born in Pittsfield, Mass., on February 25th, 1860. He was a son of Samuel Augustus Wright and Ann Maria (Butler) Wright. His father was the son of Samuel C. Wright and Olive (Benton) Wright, and traced his descent to James Wright of Milford and Durham, Mass. (1698). His mother, Ann Maria (Butler) Wright, born in Connecticut, was the daughter of Sylvester and Anna Butler, whose family traced its descent to Richard Butler, a deacon in the church of the Rev. Thomas Hooker. This is the church the members of which came from Boston and settled Hartford, Conn., in 1636.

Mr. Wright was prepared for college at the Middletown, Conn., High School and took the Civil Engineering Course at Sheffield Scientific School, Yale University, where he was a member of Phi Gamma Delta and received a Senior appointment.

After his graduation from Sheffield, Mr. Wright entered the service of Commander Garringe, U. S. N., the Consulting Engineer of Obelisk fame. In 1886, he was engaged on construction work with the Minneapolis, St. Paul and Sault Sainte Marie Railroad, and, later, was employed on the same kind of work in the Cascade Mountains for the Oregon Pacific Railroad, and, in Lower California, Mexico, for the Ferrocarril San Quintin y Yuma.

After two years more in the service of the Minneapolis, St. Paul and Sault Sainte Marie Railroad, and a year's travel, he was appointed, in 1895, Division Engineer of the Drainage Department of the Sewerage and Water Board of the City of New Orleans, La., which position he held at the time of his death on November 16th, 1919.

He was married on May 18th, 1896, in New Orleans, La., to Miss Juliette Pulver, daughter of David Barker Pulver, of that city, by whom he is survived. They had no children.

Mr. Wright had many business and professional qualities. Those who knew him always retained a high regard for his clear-sighted analysis of conditions, his high standard of fair dealing, his integrity, and his tactful treatment of all questions submitted to him. He was an engineer of unquestioned ability, active, energetic, and had endeared himself to all who knew him.

Mr. Wright was elected a Member of the American Society of Civil Engineers on November 3d, 1897. He was also a Charter Member and a Past-President of the Louisiana Engineering Society.

* Memoir prepared by Alfred F. Theard, M. Am. Soc. C. E.

CAREY SIMON PRATT, Assoc. M. Am. Soc. C. E.*

Died November 25th, 1918.

Carey Simon Pratt was born in Quincy, Ohio, on July 7th, 1868. Some time during his young manhood he decided to become a Civil Engineer and make that Profession his life work. Accordingly, from 1888 to 1891, he acquired his technical training in the Ohio State University. Almost immediately after finishing his college course he began serving the public in an official capacity as Deputy County Surveyor in Noble County, Indiana, and continued for the greater part of his life in the public service, although for certain periods he engaged in private work as a Civil Engineer.

From 1893 until 1895, Mr. Pratt served as City Engineer of Sidney, Ohio, and for three years thereafter engaged in private practice as an Engineering Contractor, later, becoming Resident Engineer for the Dayton-Springfield and Urbana Railway. From 1900 to 1902 he occupied the position of Chief Engineer of the Springfield-Xenia Electric Railroad, and, at the same time, acted as Consulting Engineer for the Western Ohio Electric Railroad. It is obvious that he was particularly active during these few years in the development, organization, and maintenance of some of the most important electric railway enterprises in that section of the country and at a time when the electric railroad was being developed at a rapid rate. Men of initiative, ingenuity, training, and ability were just as much required in those days as they were in the early history of steam railroading, and it can be truthfully said that Mr. Pratt possessed all these characteristics in a marked degree.

In 1902, he again returned to public life as City Engineer of Urbana, Ohio, and continued in that position for about eleven years. While serving in this capacity, he designed the sanitary sewer system of Urbana, embracing some fourteen miles of sewers. He also acted as County Engineer of Champaign County, Ohio, from 1902 to 1909, specializing particularly on the design and construction of highway bridges.

From 1913 to 1916 Mr. Pratt was engaged in county bridge work at Sandusky, Ohio, and was also associated with Smith and Boulay of Toledo, Ohio, Consulting Engineers, at both of which places his wide training and the experience gained in his municipal work were of the utmost advantage.

During 1916 and 1917, he supervised one of the first pieces of brick highway construction in West Virginia, just outside of Morgantown. On the completion of that project he came east in the spring of 1917

* Memoir prepared by Harry F. Harris, Assoc. M. Am. Soc. C. E.

and entered the employ of Mercer County, New Jersey, in the capacity of Bridge Engineer. He obtained the appointment to this position through a competitive examination held by the New Jersey State Civil Service Commission, having attained the highest rating of all the competitors for that position. It will be noted that his very decided liking for municipal and public work again asserted itself. Mr. Pratt served as Bridge Engineer until his untimely death.

He was always an intensive student. In fact, it can be said that his real studies did not begin until after he left college. The acquirement of technical knowledge in all the branches of engineering with which he had been connected was one of his greatest hobbies. For years he made a practice of collecting all articles describing any unusual, noteworthy, or ingenious methods for carrying out difficult construction problems, formulas, and new developments pertaining either to the technical or practical side of bridge and highway construction, and as a result of his activities in this direction he had accumulated a rather interesting collection of data and engineering literature which he greatly prized. It was this intense and constant study with so little relaxation that hastened his death.

It is indeed unfortunate that the lives of so many men should be taken just at a period when their age and experience should render them of the utmost usefulness to those they serve, and this means not only the community and mankind generally, but also their families and friends as well. Such was the case when Carey Simon Pratt died on November 25th, 1918.

In 1891 Mr. Pratt was married to Ada Belle Rogers, of Columbus, Ohio. As a result of this union three children—Mrs. Harold Houston, Helen and Lindsay Pratt—were born.

Mr. Pratt was connected with the Masonic Fraternity, in which he took a deep and ardent interest. He was a member of Champaign Lodge, Free and Accepted Masons, of Urbana, Ohio, and also a Knight Templar, belonging to Rapier Commandery of the same city. He was also a member of the American Society for the Advancement of Science.

Mr. Pratt was elected an Associate Member of the American Society of Civil Engineers on June 4th, 1913.

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"ARCHED DAMS." B. A. SMITH.

"NOTES ON TUNNEL LINING." S. JOHANNESSON and B. H. M. HEWETT. (To be presented April 21st, 1920.)

"THE DUTY OF WATER IN THE PACIFIC NORTHWEST." J. C. STEVENS.

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OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLVI—No. 4

April, 1920

Published by the American Society of Civil Engineers at its Headquarters,
33 West Thirty-ninth Street, New York, the Fourth Wednesday
of each Month, except June and July.

Entered as Second-Class Matter, December 14th, 1896, at the Post Office
at New York, N. Y., under the Act of March 3d, 1879.
Acceptance for mailing at special rate of postage provided for in Section 1103,
Act of October 3d, 1917, authorized on July 5th, 1918.
Subscription, $8 per annum.

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AMERICAN SOCIETY

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(INSTITUTED 1852)

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APRIL, 1920

Edited by the Secretary, under the direction of the Committee on Publications.

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The Reading Room of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, New Year's Day, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 6 P. M.

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Vol. XLVI. APRIL, 1920. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

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MINUTES OF MEETINGS

OF THE SOCIETY

March 17th, 1920.—The meeting was called to order at 8.30 P. M.; Director J. S. Langthorn in the chair; Herbert S. Crocker, Acting Secretary; and present, also, 169 members and guests.

The meeting was devoted to an informal discussion on "The Nation-Wide Demand for Improved Highways". The discussion was opened by H. G. Shirley, M. Am. Soc. C. E., whose subject was "General Survey of the Highway Situation". Mr. Shirley was followed by Messrs. W. G. B. Thompson on "Historical Sketch of Traffic and Types"; E. J. Mehren, on "How Much can We Afford to Spend for Highways per Mile?"; George H. Pride, on "Permissible Cost Based on Saving in Haulage"; H. Eltinge Breed, on "Need of Adequate Maintenance—Its Bearing on First Cost"; H. E. Hilts, on "Suggestions on How to Complete the 1920 Programme of Highway Construction"; Robert S. Parsons on "Permanent Highways as an Aid to Railroads"; and T. Kennard Thomson.

On motion, duly seconded, a vote of thanks was given the speakers of the evening.

The Acting Secretary announced the election of the following candidates on March 9th, 1920:

As Members

Julius Adler, Philadelphia, Pa.
William Daniel Chamberlin, San Francisco, Cal.
Christopher Tompkins Chenery, Washington, D. C.
Elmer White Clark, Pittsburgh, Pa.
John William Ferguson, Portland, Ore.
Eugene Bruce Ford, Seattle, Wash.
Henry Lehmberg Hagerman, Greenville, S. C.
Hugh Ellmaker Hale, New York City
Merrill Hibbard, Columbus, Ohio
David Henry Lane Kneedler, Philadelphia, Pa.
Harry Martin Nabstedt, Davenport, Iowa
Andrew D. Schindler, San Francisco, Cal.
Frederick E. Schmitt, Montclair, N. J.
Clarence Osborne Sherrill, Washington, D. C.
John Clayton Tracy, New Haven, Conn.
Francis Spinner Wells, Malden, Mass.
Thomas Leroy Willis, New Orleans, La.

As Associate Members

Ralph Wentworth Adams, Spokane, Wash.
Jerome Eric Barieau, East Auburn, Cal.
Henry Claus Beckman, Chicago, Ill.
Merrill Monfort Bernard, Crowley, La.
Isador Leon Birner, Omaha, Nebr.
Arthur Hazard Bond, New Haven, Conn.
Percy Dalles Brown, Philadelphia, Pa.
John Albert Charlton Callan, Austin, Tex.
Donald Eugene Ames Cameron, Toledo, Ohio
John Titreville Campbell, Pittsburgh, Pa.
Arthur William Consoer, Dallas, Tex.
Claude Carlisle Coykendall, Ames, Iowa
Frank Fitzpatrick Du Bose, Dallas, Tex.
Robert Muratt Dunlap, Chicago, Ill.
Richard Leech Elton, Kansas City, Mo.
Lewis Azro Emerson, Columbia, S. C.
Orville Alva Faris, Boise, Idaho
Georg Carl Gustav Schlichting Franck, New York City
Gilbert Houston Gilchrist, Dallas, Tex.

Albert Edward Goodwin, Sewickley, Pa.
Isaac Gutman, San Francisco, Cal.
Ross Amerson Harbaugh, Oil City, Pa.
John Kellar Harris, Sharon, Pa.
James Oliver Hogg, Jr., Kansas City, Mo.
Nicholas Firth Jahn, Seattle, Wash.
Giles Matthew Jowers, San Antonio, Tex.
Raymond Joseph Keays, Perth Amboy, N. J.
Henry Moennick Kleifeld, Spokane, Wash.
Leander Larson, Camp Eustis, Va.
James Patrick McAvoy, Albany, N. Y.
Claude Leon McKesson, Portland, Ore.
George Plummer McNear, Jr., New York City
Frederick Traugott Martius, Dallas, Tex.
Foster Gilbert Morss, Salt Lake City, Utah.
Alonzo Marsh Mutersbaugh, San Antonio, Tex.
Blaine Noice, Los Angeles, Cal.
James William Norton, Carlisle, Ky.
Frank Harry Nygren, Brooklyn, N. Y.
Chester White Ogden, Roanoke, Va.
George Orr, Atlantic City, N. J.
Edmund Nikolai Peterson, Paris, France
Ralph Whitney Reynolds, New York City
Harry Norman Roberts, Longview, Tex.
Walter Harold Root, Ames, Iowa
Nicholas A. Saigh, Camp Travis, Tex.
Mark Sebastian Sanders, Kobe, Japan
Edward Goodrich Semon, Albany, N. Y.
Harry A. Seran, Pensacola, Fla.
Will Gerald Shurgar, Meridian, Miss.
Merril Forester Snell, Pittsburgh, Pa.
Frank Charles Tews, Spokane, Wash.
Willis Gersham Waldo, Chattanooga, Tenn.
Howard Charles Wickes, Cincinnati, Ohio
Nathan Wohlfeld, Dallas, Tex.
Lester Oren Wolcott, Fresno, Cal.

As Associates

John Notman Thorp, Jr., Chicago, Ill.

As Juniors

Avey Martin Baker, New York City
Harold Rhodes Bassett, Washington, D. C.
Irwin Eugene Burks, Springfield, Mo.
Jerome Brasil Francis Crowley, New York City

Victor Timothy Givotovsky, New York City
Michael Charles Grenata, Camp A. A. Humphreys, Va.
Albert Haertlein, Cambridge, Mass.
Cho-Pin Hsueh, Ithaca, N. Y.
George Alvin Nordgren, Chicago, Ill.
Francis Harloe Phipps, Mount Vernon, N. Y.
Frank Martin Schilling, Philadelphia, Pa.
Chen Tan, Ithaca, N. Y.

The Acting Secretary announced the transfer of the following candidates on March 9th, 1920:

From Associate Member to Member

Eugene Yorke Allen, New York City
Harold Willoughby Benedict, Troy, N. Y.
Roy Winchester Crum, Ames, Iowa
Howard Kingsbury Holland, Ann Arbor, Mich.
Hugh Browning Holmes, New York City
Elmer Thomas Howson, Chicago, Ill.
Battle Hargrove Klyce, Nashville, Tenn.
Albert Larsen, Dayton, Ohio
Leon Roderick MacKenzie, Des Moines, Iowa
Franklin R. McMillan, Philadelphia, Pa.
Neal Albert Melick, Newark, N. J.
Herbert Drummond Mendenhall, Lakeland, Fla.
William Taft Newcomb, Easton, Pa.
Charles William Okey, Peoria, Ill.
Fred Dale Pyle, Montrose, Colo.
Robert Isham Randolph, Chicago, Ill.
Arthur Richards, Columbus, Ohio
Arthur Valentine Ruggles, Cleveland, Ohio
Charles Herman Ruggles, West Palm Beach, Fla.
Arthur Johnson Sackett, Newark, N. J.
Alfred George Schutt, Detroit, Mich.
Eugene Adalbert Silagi, Columbus, Ohio
Joseph Springer Swindells, New York City
Lyle Antrim Whitsit, Tokyo, Japan

From Associate to Associate Member

Frank Louis Reynolds, New York City

From Junior to Associate Member

Otto William Julius Anschuetz, St. Louis, Mo.
Philip Gilstrap Bruton, Buffalo, N. Y.
Ira Leonard Collier, Seattle, Wash.
Harold Bernard Hammill, Berkeley, Cal.

Maurice William Hewett, Minneapolis, Minn.
John James Hurley, Dayton, Ohio
David Howe Lucchesi, Jr., Baltimore, Md.
John Siemon Means, Denver, Colo.
George John Meise, New York City
Melvin Lyman Moone, Lansing, Mich.
Chelius Hazel Shea, Piqua, Ohio
William Davis Shipman, Chicago, Ill.
Charles Smith Whitney, Milwaukee, Wis.

The Acting Secretary announced the following deaths:

John Abiel Atwood, of Pittsburgh, Pa., elected member, January 3d, 1900; died February 29th, 1920.

George Barker Burbank, of New York City, elected Member, July 4th, 1888; died February 29th, 1920.

Andrew Christian Hansen, of Los Angeles, Cal., elected Member, October 4th, 1910; died February 9th, 1920.

Orlando Whitney Norcross, of Worcester, Mass., elected Member, October 31st, 1911; died February 27th, 1920.

Adjourned.

April 7th, 1920.—The meeting was called to order at 8.30 P. M.; Vice-President Herbert S. Crocker in the chair and acting as Secretary; and present, also, 85 members and guests.

The minutes of the Annual Meeting, January 21st, 1920, and of the meetings of February 4th, February 18th, and March 3d, 1920, were approved as printed in *Proceedings* for February and March, 1920.

A paper by Herbert C. Keith, M. Am. Soc. C. E., entitled "A Novel Method of Repairing a Swing Bridge", illustrated with lantern slides, was presented by the author and his son, G. M. Keith, Jun. Am. Soc. C. E. The subject was discussed by Messrs. J. B. French, T. Kennard Thomson, Guy Pinner, Charles Rufus Harte, T. Hugh Boorman, O. E. Hovey, Frank W. Skinner, Theodore Belzner, Shortridge Hardesty, and Arthur S. Tuttle.

The Acting Secretary announced the following deaths:

Frederick Thomas Hatch, of St. Louis, Mo., elected Member, December 4th, 1889; died March 9th, 1920.

George Blagden Hazlehurst, of Cantonsville, Md., elected Member, February 1st, 1888; died May 27th, 1919.

Alfred Raymond, of New Orleans, La., elected Member, September 6th, 1910; died January 13th, 1920.

Ellis Dunn Thompson, of Philadelphia, Pa., elected Member, February 1st, 1899; died February 9th, 1920.

George Wellman Parsons, of Steelton, Pa., elected Associate, September 3d, 1884; died August 15th, 1919.

Adjourned.

ITEMS OF INTEREST

The Committee on Publications will be glad to receive communications of general interest to the Society, and will consider them for publication in *Proceedings* in "Items of Interest". This is intended to cover letters or suggestions from our membership concerning matters which are not of a technical character. Such communications, however, must not be controversial or commercial.

NATIONAL SERVICE DEPARTMENT OF ENGINEERING COUNCIL.

In response to frequent expression of need, Engineering Council announces the establishment of a National Legislative and Departmental Information Service for engineers in all branches of the Profession. Information relative to engineering statistics, research, and construction, as well as of matters before Congress involving engineering considerations, will be furnished without charge by addressing M. O. Leighton, National Service Representative of Engineering Council, 502 McLachlen Building, Washington, D. C. This National Service Department of Engineering Council announces that its office at Washington is open to members of the Society at all times, and that accommodations can be had there at short notice for committee meetings of the Society, or of any organization in which the Society is interested, which may be held in Washington.

Charles F. Rand Elected Chairman of Engineering Foundation Board

At a special meeting of the Engineering Foundation Board on March 12th, 1920, the resignation of Dr. W. F. M. Goss as Chairman of the Board, dated February 14th, was accepted with regret and appreciation of his able services. On nomination of the Executive Committee, Charles F. Rand, who was President of the United Engineering Society for four years up to last January,* was elected Chairman for the term ending in February, 1921.

Information Bureau and Memorials for Engineering Societies Building

After consideration of a letter from John P. Hogan, M. Am. Soc. C. E., proposing a memorial tablet to the 11th Engineers, and a letter by Secretary Alfred D. Flinn, M. Am. Soc. C. E., to the Committee on War Memorials in regard to a permanent exhibition of flags of selected engineer regiments, it was voted at the regular meeting of the Trustees of United Engineering Society on March 25th, 1920,

* See *Proceedings*, Am. Soc. C. E., March, 1920, p. 335.

that the President should appoint a Committee to report upon: (1) the establishment of a general information bureau and reading room; (2) furnishing of the Entrance Hall, and (3) war and other memorials. The following were appointed to act on this Committee:

E. Gybbon Spilsbury, M. Am. Soc. C. E., Chairman; Clemens Herschel, Past-President, Am. Soc. C. E.; Calvert Townley, and J. V. W. Reynders, M. Am. Soc. C. E.

ACTIVITIES OF ENGINEERING COUNCIL

Board for Jurisdictional Awards in the Building Industry

Rudolph P. Miller, M. Am. Soc. C. E., representing Engineering Council on the Board for Jurisdictional Awards in the Building Industry, reports that the work of this Board is proceeding most satisfactorily, and that there is a feeling, particularly among the labor unions, that its work will be very helpful in adjusting difficulties which lead to strikes. One labor representative stated at the meeting held in Washington, D. C., March 8th to 11th, 1920, that the Board had accomplished in a few days what the contending organizations had failed to do in some years. At this meeting there were present: E. J. Russell, American Institute of Architects; Rudolph P. Miller, Engineering Council; J. R. Wiggins, Associated General Contractors; F. J. C. Dresser, Associated General Contractors; E. M. Craig, National Association of Building Trades Employers; Thomas Preece, John T. Cosgrove, and John H. Hynes, Building Trades Department, American Federation of Labor. The following controversies between international unions were considered and disposed of:

1.—Controversy between the Amalgamated Sheet Metal Workers' International Alliance and the United Association of Plumbers, Steam Fitters, and Steam Fitters' Helpers, concerning air washers, fans, blowers, the housing of same, and the pipe fitting on same. An agreement between the two contending organizations was submitted, which agreement was confirmed by the Board.

2.—Controversy between the United Association of Plumbers, Steam Fitters, and Steam Fitters' Helpers, and the International Union of Steam Engineers, on the question of maintaining temporary heat while structures are in course of construction. Argument was heard on both sides, and jurisdiction was given to the steam fitters "until the initial test is completed, immediately after which time, whenever necessary to maintain heat a stationary engineer (union of Steam Engineers) shall be employed".

3.—Controversy between the Bridge and Structural Iron Workers' International Association and the United Association of Plumbers and Steam Fitters, as to the installation of threaded pipe. After hearing

argument, it was decided that "Pipe railing consisting of standard sized, cut and threaded pipe, not used in connection with structural or ornamental iron work, is awarded to the United Association of Plumbers and Steam Fitters".

4.—Controversy between Operative Plasterers and Cement Finishers' International Association and the Wood, Wire and Metal Lathers' International Union, on the question of the placing of corner beads. After hearing argument, it was decided that "the adherence of corner beads by plastic material" technically known as "sticking", belongs to the plasterers.

5.—Controversy between the Amalgamated Sheet Metal Workers' International Association and the Brotherhood of Painters and Decorators, as to the glazing of sheet metal sash frames, doors or skylights. An agreement made between these contending organizations on this subject was submitted, and the matter was accordingly dismissed.

6.—Controversy between the Bridge and Structural Iron Workers' International Association and the Wood, Wire and Metal Lathers' International Union, on the placing of reinforcement for reinforced concrete, cement and floor construction. After hearing argument, it was decided "that all iron and steel used for reinforcement in reinforced concrete, cement and floor construction" should be awarded to the iron workers. It was, however, to be understood that in such cities or localities where there are existing agreements between employers and the lathers' union, such agreements should continue in force until their expiration under the terms of the agreement, after which the decision made shall prevail.

7.—Controversy between the International Brotherhood of Electrical Workers and the Elevator Constructors' International Union, on the matter of electrical work in connection with elevators. After discussion, it was decided that the electrical work of flash lights, electrical annunciators and lamps and feed wires, remain, as heretofore, in the control of the electrical workers. Other electrical work is to be done by the elevator constructors.

8.—Controversy between the Bricklayers, Masons and Plasterers' International Union and the Brotherhood of Painters, Decorators and Paper Hangers, as to the setting of vitrolite and other opaque glass. After hearing argument, it was decided that "Jurisdiction over the setting of vitrolite and similar opaque glass, is awarded to the Bricklayers, Masons and Plasterers' International Union."

9.—Controversy between the Bricklayers, Masons and Plasterers' International Union and the International Brotherhood of Electrical Workers, with respect to the cutting of chases or channels in masonry. After hearing argument, it was decided that when channels do not exceed 2 by 2 in. in size, or do not require labor exceeding 8 hours continuous work, it may be done by the electrical workers. Other

channels, chases, or grooves in masonry of all kinds, necessary to the installation of electrical work, must be done by the bricklayers. It was to be understood, however, that this decision does not contemplate the channelling or cutting of granite or hard stone.

10.—Controversy between the Bricklayers, Masons and Plasterers' International Union and the Bridge and Structural Iron Workers' International Association, over the erection and operation of stone derricks. Inasmuch as the representatives of the two unions stated that an effort was being made to adjust this between them, and that the prospect of such adjustment was good, the matter was dismissed from further consideration by the Board.

11.—Controversy between the International Association of Amalgamated Sheet Metal Workers and the Bridge and Structural Iron Workers' International Association, over the erection of corrugated sheeting. The representatives of the two organizations stated that they were then conferring on this matter, and requested permission to adjust the matter outside of the Board. In view of this statement, the matter was dismissed.

American Railway Engineering Association Elected a Member of Engineering Council

In accordance with the proposal of Chairman J. Parke Channing in a communication to the United Engineering Society dated March 19th, 1920, and the unanimous approval of the representatives of the Founder Societies in Engineering Council, it was voted at the regular meeting of the Trustees of United Engineering Society on March 25th, 1920, as follows:

"That the American Railway Engineering Association be invited and elected to membership in Engineering Council, subject to the unanimous approval of the governing bodies of the four Founder Societies, and that upon receipt by the Secretary of information of such approval, the invitation be extended to said Association to become a member of Engineering Council, upon acceptance of the invitation and compliance with the requirements of the Rules for Admission of Additional Societies".

The American Railway Engineering and Maintenance of Way Association was organized in 1899 with the object of "the advancement of knowledge pertaining to the scientific and economical location, construction, operation and maintenance of railroads"; the name was changed in 1911 to its present form and the Association now has about 1 640 members. The President is H. R. Safford, M. Am. Soc. C. E., Assistant to President, Chicago, Burlington and Quincy Railroad, and the Secretary is E. H. Fritch, 431 South Dearborn Street, Chicago, Ill.

John Fritz Medal to be Presented to Orville Wright on May 7th

The John Fritz Medal for 1920 has been awarded to Orville Wright, Esq., for achievement in the development of the airplane. At a meeting in the auditorium of the Engineering Societies Building on May 7th, 1920, at 8.30 P. M., at which the principal speakers will be Gen. George O. Squier, Chief Signal Officer, and Col. Edward A. Deeds, of Dayton, Ohio, formerly of the Aircraft Production Board, the presentation will be made by Prof. Comfort A. Adams. Mr. B. B. Thayer, present chairman of the John Fritz Medal Board of Award, will preside. A cordial invitation to attend is extended to all members of the Society.

The previous recipients of this medal have been:

John Fritz	1902
Lord Kelvin	1905
George Westinghouse	1906
Alexander Graham Bell	1907
Thomas Alva Edison	1908
Charles Talbot Porter	1909
Alfred Noble	1910
Sir William Henry White	1911
Robert Woolston Hunt	1912
John Edson Sweet	1914
James Douglas	1915
Elihu Thomson	1916
Henry Marion Howe	1917
J. Waldo Smith	1918
George W. Goethals	1919

American Engineering Standards Committee

At a meeting of the American Engineering Standards Committee on March 6th, 1920, it was voted to grant Secretary P. G. Agnew leave of absence in order to attend the meeting of the International Electrotechnical Commission in Brussels, Belgium. Dr. Agnew left on March 13th, 1920, expecting to be abroad about six weeks, and to spend some time in London and Paris studying British and French standardization organizations. Dr. J. F. Meyer, of the United States Bureau of Standards, was given charge of the office during Dr. Agnew's absence.

Mr. R. B. Woodworth, of the Association of American Steel Manufacturers, was elected permanent chairman of the Sectional Committee on Steel Shapes, for which the Society is one of the sponsor bodies, President A. P. Davis having appointed H. G. Balcom, J. H. Edwards and J. B. French, Members Am. Soc. C. E., as its representatives on said Sectional Committee. This Committee has approved the use of

two-place decimals of an inch in the determination of profiles of structural shapes; has adopted the recommendation of the Association of American Steel Manufacturers that practical, definite ranges of thickness and weights per foot for each shape be used in accordance with American standard practice; has voted that the gradations in range of thickness be expressed in multiples of 0.04 in., and that there should be but one line of channel sections for both structural and shipbuilding uses.

Five standards have been submitted by the American Society for Testing Materials for the approval of the American Engineering Standards Committee as follows: Specifications for Drain Tile; Test for Toughness of Rock; Test for Penetration of Bituminous Materials; Test for Distillation of Bituminous Materials Suitable for Road Treatment, and Method for Sampling Coal. A Committee consisting of George E. Thackray, M. Am. Soc. C. E., Chairman, Fred E. Rogers, and Martin Schreiber, M. Am. Soc. C. E., was appointed to consider these standards, and it is expected that action will be taken upon its recommendation at the next meeting of the Standards Committee on June 5th, 1920.

The Tunnel Under the English Channel

The project of tunneling the English Channel dates back to about 1802, when an engineer named Mathieu submitted a scheme to Bonaparte, and it has been presented repeatedly to the British and French Governments. Prior to the European war the main objection which prevented procedure with the work was the fear on the part of the military authorities in Great Britain that it would destroy the protection which the Channel gave to the British Isles. This condition has been totally changed by the War and by the development of the navigation of the air, and it is understood that the British military and naval authorities now favor the project, provided the English end is controlled by these British authorities.

As to the geological conditions which govern the situation, it may be said that what is now the English Channel was probably caused by a gradual subsidence of the land and not by any violent cataclysm, consequently there is every reason to believe that the stratification continues intact and uniform from the southerly counties of England across the Channel and through the northern region of France.

In the first scheme, proposed by Mathieu, the tunnel was divided into two parts, each part being about 10 miles long and each opening on to a submarine bank situated nearly in the centre of the Dover Straits. This submarine bank was to be raised and formed into a large island, and on this artificial island a town was to be erected, together with a large harbor. This scheme was not based on any really serious study, and of course brought no result.

During 1882 and 1883 considerable lengths of experimental sections of tunnel were built from the French and British shores. It is proposed to continue the construction of the tunnel throughout as planned at that time, placing it about 180 ft. below the level of the sea in a stratum of gray chalk, which is about 200 ft. thick and which it is believed is impervious to water, and so far as geological investigation can show free from faults and fissures. The shores on the French and British sides of the Channel are fronted with high chalk cliffs and it is necessary to extend the tunnel a long distance back of the cliffs on either side before the tracks can be brought to the surface of the land and connected with the main line railroads. The total length of the tunnel from surface to surface would be approximately 32 miles, whereas the length under the Channel would be about 23 miles.

The present plans, as now developed, contemplate two twin bores lined with reinforced concrete. Each tunnel would take one line of track and would be about 20 ft. in external diameter, 18 ft. in internal diameter, lined with reinforced concrete and driven by the aid of mechanical excavators by which a high rate of progress can be attained in this chalk.

Had this tunnel been in existence during the World War, enormous sums of money would have been saved to the Allies and greatly increased efficiency would have been obtained in the handling of troops and supplies. The dire necessity for better communication between Great Britain and the European continent was met by the establishment by the British Government of lines of train ferries between Richborough and Dunkirk, Richborough and Calais, and Southampton and Dieppe. A line between Southampton and Cherbourg is also being started. The boats used have a length of 363 ft., beam 61½ ft., draft 12 ft., displacement of 3 650 tons, and a speed of 12 knots. They have four rail tracks and carry fifty-four 10-ton railroad cars.

The tunnel necessitates the installation of electric power for operation. Had the tunnel been built 40 or 50 years ago when active efforts were being made to push the project for adoption, the railroad probably would never have been operated on account of the difficulties of ventilation, with the motive power then available. The development of electric power for operation has revolutionized the entire situation and apparently there is no longer any objection from the military point of view to carrying out the project.

It is estimated in a recent article in the *London Times* that the tunnel, by the use of all modern mechanical appliances, could be driven in four years exclusive of lining and equipment.

An initial service of 15 passenger trains per day in each direction would provide for some 1 500 000 passengers per annum; as the traffic grew more trains could be provided. There would be sufficient periods of the day left in which the freight traffic could be taken care of, either

during such times as the passenger trains were not running, or sandwiched in between. This tunnel would provide rail connection between England and the Continent, not merely with France, but with the entire European system of railroads, the gauge of which is practically the same as in England.

There appears to be absolutely no engineering or physical reasons why there should be any doubt about the success of the undertaking, and while there might be a few years at the start of operation during which there would be a deficit, this could be taken care of by some form of guarantee by the British, French, and Belgian Governments; and now that political and military obstacles seem to have been removed, a short time should see the inception of this long-delayed and much-needed connection.

The "Military Engineer", Successor to "Professional Memoirs"

Aiming to enter a larger field and operate on a broader basis than its predecessor *Professional Memoirs,* and to form a bond of union between all members of the Engineering Profession who are interested in the National defense, *The Military Engineer* has just been issued as the journal of the Society of American Military Engineers. It is published bi-monthly at Washington Barracks, D. C.

EUROPEAN NOTES

The following notes relative to reconstruction, etc., in Belgium and France, and industrial progress, etc., in Great Britain and elsewhere, have been contributed by W. E. Woolley, Assoc. M. Am. Soc. C. E., of London, England, who is also a Corresponding Member of the Association of Liége (Belgium) Architects.

Liége Council Votes Credits for House Construction

The town council of Liége has voted a credit of 5 000 000 francs for the construction of working class dwellings, for the purchase and fitting up of existing house property, also for the construction of temporary dwellings. It has also decided to create a letting agency.

An exhibition is to be held shortly at the Museum, Rue de l'Academie, Liége, of the designs awarded premiums in the recent competition organized by the High Commissioner for the devastated regions of Liége, Namur, and Luxemburg.

Industrial Research in Belgium

The Office of Industrial Research in Belgium, which is under the Ministry of Economic Affairs, is studying problems which are of great importance to Belgium at the present time, such as economies effected

in fuel by electrification, and the manufacture of ammonia compounds and nitrates, in order to diminish imports of these. It is proposed to establish a laboratory for research and study of materials of construction, of industrial products, etc., to aid and encourage inventors, and to co-operate with foreign or international organizations having the same objects.

The American Monument on the Marne

The *Petit Parisien* announces that the American monument on the Marne will shortly be erected on a site chosen by Marshals Joffre and Foch.

The monument will be a replica of the Statue of Liberty in New York Harbour, and will probably be unveiled on July 4th, American Independence Day, or July 14th, the French Fête Nationale.

Turf as Engine Fuel

The Swedish Department of Railways has announced that it intends to develop the production of turf fuel for locomotive firing.

The experiment with turf as railway fuel began in 1917, and in the following year turf was being cut in eleven different districts, and the production reached 40 000 tons. Last year turf was in widespread use both in stationary engines and in locomotives. Experience showed that it was fully suitable for slow freight trains and for shunting locomotives, but was less suitable for fast passenger trains.

Economically considered, turf is more profitable than coal at present high prices for the latter.

BRIEF NOTES

Secretary of War Baker, after an inspection of the Rock Island Arsenal, is reported as enthusiastic over the plan of employees representation which is there in force, by which a committee composed of three representatives elected from each department takes up all grievances and gives the men a direct voice in the management of the Arsenal.

According to an announcement by the Inter-racial Council, of New York City, 275 000 emigrants have left this country since the armistice, taking $550 000 000 with them, while during the same period immigration has consisted largely of war widows, and other women or industrial non-producers.

By using Hertzian waves, wireless experts of the British fleet have succeeded in controlling torpedo craft from a distance of some miles.

Negotiations with Great Britain are under way in Brussels for a loan of £5 000 000 to be used for reconstruction of the devastated districts of Belgium.

According to official statistics of the American Iron and Steel Institute, 1919 pig iron production in the United States was 31 015 364 tons, as compared with 39 054 644 tons the preceding year. The output in 1917 was 38 021 216 tons, and in 1916, 39 434 797 tons, the production in 1916 being the largest of any year in the history of the industry. The annual report of the U. S. Steel Corporation shows earnings for 1919 of $152 290 639, a decrease of $55 990 465 as compared with 1918.

Lt.-Col. K. Mixer, Red Cross Commissioner to France, states that the return to normal conditions in France is going on so rapidly that 4 300 000 inhabitants of the 4 700 000 who in pre-war days occupied the devastated areas have returned to their homes and will have the region under cultivation within a year. Col. Mixer announces that similar progress is being made in Belgium.

It is announced in London that steps have been taken for the formation of the most powerful banking combine in the history of peace-time finance for restoring industry and economic life of central Europe. Participants in the organization are Lloyds Bank, London Joint City and Midlands Bank, Frederick Huth and Co., Morgan, Grenfell and Co., Coschen and Cunliffe, Rothschild and Sons and Schroeder and Co. It is said to be a practicable scientific scheme along the lines of a semi-barter system by which raw materials will be allowed to flow into central Europe.

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, New Year's Day, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 6 P. M.

FUTURE MEETINGS

May 5th, 1920.—8.30 P. M.—A regular business meeting will be held, and a paper by Allen Hazen, M. Am. Soc. C. E., entitled "Hydraulic-Fill Dams", will be presented for discussion.

This paper is printed in this number of *Proceedings*.

May 19th, 1920.—8.30 P. M.—The usual meeting will be held on this evening, and announcement of the programme will be made later.

ENGINEERING SOCIETIES EMPLOYMENT BUREAU

Engineering Societies Employment Bureau, established December 1st, 1918, as an activity of Engineering Council, is managed by a board made up of the Secretaries of the four Founder Societies, funds for its maintenance being provided by these Societies. The Bureau is co-operating with engineering organizations in all parts of the country and with the Re-employment Bureau under the auspices of the American Legion. It is desirous of increasing such co-operation by working with local engineering associations and clubs. The work of the Bureau since its inception has been largely in the line of securing employment for men retiring from government war service. Members of the American Society of Civil Engineers who desire to register with this Bureau should apply for further information, registration forms, etc., to Walter V. Brown, Manager, Engineering Societies Employment Bureau, First Floor, Engineering Societies Building, 29 West 39th Street, New York City.

SEARCHES IN THE LIBRARY

As the Library of the American Society of Civil Engineers has been merged in the Engineering Societies Library, requests for searches, copies, translations, etc., should be addressed to the Director, Engineering Societies Library, 29 West 39th Street, New York City, who will gladly give information concerning the charges for the various kinds of service. A more comprehensive statement in regard to this matter will be found on page 21 of the Year Book for 1920.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written

communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion will be published as heretofore in *Proceedings,* and set down for presentation to a future meeting of the Society, and, on these, oral discussion, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 35 of the Year Book for 1920.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association, Organized 1905.

M. M. O'Shaughnessy, President; Nathan A. Bowers, Secretary-Treasurer, 502 Rialto Building, San Francisco, Cal.

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Engineers' Club, 57 Post Street, on the third Tuesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at noon, every Wednesday, at the Engineers' Club, where special tables are reserved for members and guests of the Association.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association, Organized 1908.

W. C. Huntington, President; A. N. Miller, Secretary-Treasurer, 1400 West Colfax Avenue, Denver, Colo.

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place

of meeting are not fixed, but this information will be furnished on application to the Secretary. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesday, at 12.30 P. M., at Daniels and Fisher's.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meetings)

December 13th, 1919.—The meeting was called to order at the Shirley Hotel; Vice-President Oliver T. Reedy in the chair; A. N. Miller, Secretary; and present, also, 11 members and 1 guest.

The minutes of the previous meeting were read and approved.

On motion, duly seconded, it was voted that the Chair appoint a committee to prepare a memoir of the late Thomas W. Jaycox, M. Am. Soc. C. E., and Mr. Lyman E. Bishop was appointed as such committee.

Mr. Arthur Ridgway, the Association's representative in the Colorado Engineering Council, called attention to the fact that the terms of office of the representatives in the Council expired on January 1st, 1920, and, on motion, duly seconded, it was voted to reinstate the present incumbents, namely, Mr. Ridgway as representative and Mr. E. F. Vincent as alternative.

Capt. H. G. Burrowes addressed the meeting on "The Work of the Engineer Regiments in France", and Maj. W. B. Freeman described the work of the 509th Engineers and discussed briefly the character and relative efficiency of the common labor with which he had come in contact in France.

Adjourned.

January 10th, 1920.—The meeting was called to order at Baur's Café; Vice-President Oliver T. Reedy in the chair; A. N. Miller, Secretary; and present, also, 10 members and 1 guest.

The Secretary read a letter from the Philadelphia Association requesting favorable action on the report of the Development Committee. He also read a letter from the Northwestern Association outlining the action of its members relative to the report.

On motion, duly seconded, it was decided that no action would be taken on these letters until after Mr. Thomas L. Wilkinson had addressed the meeting on the subject.

Mr. L. R. Hinman reported in the matter of tunneling the Continental Divide and stated that, owing to certain difficulties in the way of getting together, he doubted the feasibility of further work by the Committee. The Chairman, however, suggested that the work of the Committee be continued.

Mr. Wilkinson addressed the meeting on the report of the Development Committee, after which, on motion, duly seconded, the following resolutions were adopted:

"That this Section endorses the action of the Committee on Development of the American Society of Civil Engineers and favors the adoption of its report as a whole and its present form.

"That a copy of the above resolution be sent to the Board of Direction, to the Committee of the Board of Direction to Review the

Report of the Committee on Development, and to Mr. George G. Anderson with the request that he act as the representative of the Association at the Annual Meeting."

Adjourned.

February 14th, 1920.—The meeting was called to order in the dining-room of the Union Station; President W. C. Huntington in the chair; Vice-President O. T. Reedy acting as Secretary; and present, also, 13 members and 4 guests.

An informal discussion of the Federal Aid Road Work was opened by Mr. A. E. Palen, Senior Highway Engineer of the Bureau of Public Roads.

Mr. L. R. Hinman, Chairman of the Committee appointed to investigate the matter of securing data in connection with the proposed tunnel through the Continental Divide, presented a report of that Committee.

On motion, duly seconded, the report was accepted and the Committee discharged, after which there was a lengthy discussion of the subject.

(President Huntington being obliged to leave, the meeting called Vice-President Reedy to the chair.)

Mr. Arthur Ridgway, President of the Local Engineering Council, called the attention of the members present to the matter of response to calls for individual contributions for the support of National Engineering Council and of the suggested unification of the engineering works of the State along lines similar to the proposed Federal Department of Public Works.

The Secretary read a communication from the Secretary of the Joint Council of Engineering Societies of San Francisco, calling attention to an enclosed set of resolutions endorsing Herbert C. Hoover, M. Am. Soc. C. E., for President, and inviting engineering bodies of the United States to join with it in furthering Mr. Hoover's nomination and election.

Mr. F. E. Weymouth called attention to the provision of the Esch Water Power Bill to detail an Army Officer as Executive Secretary and Engineer Officer of the proposed Water Power Commission. After considerable discussion of the subject it was decided, on motion, duly seconded, that a committee of three be appointed to secure all the data possible in regard to this matter to be presented to a called meeting of the Association, in order that the question of protesting this provision might be discussed. The Chairman appointed Messrs. Weymouth, Ridgway, and Hinman as such Committee.

Adjourned.

February 18th, 1920.—The Special Meeting was called to order at Daniels and Fisher's Tea Room; Vice-President O. T. Reedy in the chair; A. E. Palen, acting as Secretary; and present, also, 16 members and 1 guest.

The special meeting was called by the Executive Committee for the purpose of receiving and considering the report of the Committee appointed to secure certain data in regard to the Esch Water Power Bill now before Congress, and was held in connection with the regular weekly luncheon of the Association.

Mr. F. E. Weymouth, Chairman, presented the report of the Committee, and the subject was discussed by those present.

On motion, duly seconded, the following resolutions were adopted:

"*Whereas,* Section 2 of the Water Power Bill, H. R. 3184, as amended, provides for the appointment of an officer of the Engineer Corps of the Army as Executive Secretary and Engineer Officer of the Commission, and

"*Whereas,* The justification of such designation is based upon erroneous reasoning because, first: no ultimate economy would actually result therefrom, for if the duties of such officer of the Engineer Corps were essential, and the presumption is that they are essential or otherwise there would be no such officer in the Engineer Corps, then some other person must of necessity be designated to succeed the Engineer Corps Officer detailed to the work of the Commission; second: the permissible period of detachment of Army Officers from their regular duties would in no wise insure tenure of office as Executive Secretary and Engineer Officer of the Commission than a civilian incumbent thereof; and third: it can by no means be maintained as an established fact that officers of the Army Engineer Corps possess more of the necessary qualifications, either through training or experience in water power matters, than civilian engineers, and

"*Whereas,* We believe it in the interest of the people to leave to the discretion of the Commission the appointment of an Executive Secretary and Engineer Officer to the end that the highest qualifications may govern, regardless of whether those qualifications are to be found in the personnel of the Army or in civil life;

"*Now, Therefore, Be it Resolved* by the Colorado Association of Members of the American Society of Civil Engineers that the first sentence of Section 2 of the Water Power Bill, H. R. 3184, be struck out and the following sentence be substituted therefor:

" 'That the Commission shall appoint, fix the compensation and prescribe the duties of an Executive Secretary and Engineer Officer who shall be a properly qualified Engineer', and

"*Be it Further Resolved* That a counterpart of these resolutions be transmitted forthwith to each of the Congressional Senators and Representatives of the State of Colorado."

On motion, duly seconded, it was voted to send a copy of these resolutions to the Chairman of the Joint Conference Committee considering the bill. It was also decided to furnish the *Rocky Mountain News* with a report of the meeting and advise the other engineering societies of Denver of the action of the Association, with the request that they take similar action.

Adjourned.

Atlanta Association, Organized 1912.

V. H. Kriegshaber, President; Howard L. Stillwell, Secretary-Treasurer, 533 Trust Co. of Georgia Bldg., Care, Southeastern Underwriters' Association, Atlanta, Ga.

Informal luncheons are held for members of the Association on the last Monday of each month, at 12.30 P. M., to which visiting members

of the American Society of Civil Engineers will be welcomed. The place is not fixed, but this information will be furnished on application to the Secretary.

Baltimore Association, Organized 1914.

H. G. Perring, President, 3206 Carlisle Avenue, Baltimore, Md.

Cleveland Association, Organized 1914.

W. P. Brown, President; George H. Tinker, Secretary-Treasurer, 516 Columbia Building, Cleveland, Ohio.

The regular meetings of the Association are held on the second Wednesday of each month, at 12.15 P. M., in the Rooms of the Electrical League, on the Fourteenth Floor of the Statler Hotel. Luncheon is served at these meetings, and visiting members are invited to attend.

Connecticut Association, Organized 1919.

C. M. Saville, President; R. J. Ross, Secretary, Municipal Building, Hartford, Conn.

The Annual Meeting of the Association is held in April. The Association also holds fortnightly meetings alternating between Hartford and New Haven, Conn. These meetings are informal luncheon gatherings held usually at noon on Saturday, a notice being mailed to each member calling attention to the date, time, place, and subject for discussion. Members are privileged to invite guests regardless of their affiliation as engineers. No set speeches are scheduled, but certain members are asked to be prepared to present the assigned subject and lead in a general discussion.

Detroit Association, Organized 1916.

Lewis M. Gram, President; Dalton R. Wells, Secretary-Treasurer, 624 McKerchey Building, Detroit, Mich.

The regular meetings of the Association are held on the second Friday of December, April, and October, the last being the Annual Meeting.

District of Columbia Association, Organized 1916.

David S. Carll, President; James H. Van Wagenen, Secretary-Treasurer, 719 Fifteenth Street, N. W., Washington, D. C.

Duluth Association, Organized 1917.

G. A. Taylor, President; Walter G. Zimmermann, Secretary, Wolvin Building, Duluth, Minn.

The regular meetings of the Association are held at noon on the third Monday of each month (usually at the Kitchi Gammi Club), with luncheon, followed by a short business session and the reading of papers. Visiting members of the American Society of Civil Engineers can secure from the Secretary definite information relative to the meetings, at which they will be welcomed. The Annual Meeting is held on the third Monday in May.

Illinois Association, Organized 1916.

A. F. Reichmann, President; W. D. Gerber, Secretary-Treasurer, 913 Chamber of Commerce, Chicago, Ill.

The regular meetings of the Association are held on the second Monday of March, June, September, and December, the last being the Annual Meeting. The hour and place of meetings are not fixed, but this information will be furnished on application to the Secretary.

Iowa Association, Organized 1920.

J. E. Van Liew, President; R. W. Crum, Secretary, Iowa State College, Ames, Iowa.

(Abstract of Minutes of Meetings)

November 20th, 1919.—The meeting was called to order, at Des Moines, Iowa; President J. E. Van Liew in the chair; R. W. Crum, Secretary; and present, also, 16 members and 3 guests.

Papers by Messrs. J. H. Dunlap and W. J. Schlick on "Organization of Engineers in Iowa" and "An Outline Plan of Organization for the Engineering Council of Iowa", respectively, were presented by the authors, and were followed by a general discussion of the subject.

On motion, duly seconded, the following resolution was adopted:

"That a Committee, consisting of Messrs. J. E. Van Liew, C. H. Currie, J. H. Dunlap, and W. J. Schlick, be appointed to confer with representatives from other sections of National societies and local engineering clubs and State Engineering organizations, concerning State-wide co-operation and to report at the next meeting."

On motion, duly seconded, it was decided that the Association go on record as favoring an all-State engineering organization.

A paper entitled "Family Relations", by Mr. W. G. Raymond, was presented by the author, and, after further discussion of the subject, it was decided, on motion, duly seconded, that the recommendations of the Seattle Association and the general problems involved therein be referred to the Executive Committee for report at the next meeting.

On motion, duly seconded, it was decided that the next meeting of the Association be held in connection with the Annual Meeting of the Iowa Engineering Society.

It was also decided, on motion, duly seconded, that the officers serving at this time be considered as *pro tem.*

The following officers were elected: President, J. E. Van Liew; Vice-President, C. H. Currie; and Directors, C. L. Huff and J. B. Marsh.

On motion, duly seconded, the dues for 1920 were fixed at $5 00.

On motion, duly seconded, the following amendment to the By-Laws was ordered sent to letter-ballot to the members of the Association:

"Article VII.—All members of the American Society of Civil Engineers exempt from payment of dues in that Society be exempt from payment of dues in this Association."

The Secretary, on motion, duly seconded, was instructed to send copies of the papers by Messrs. Raymond, Dunlap, and Schlick to all members of the Association.

Adjourned.

February 17th, 1920.—The meeting was called to order at Fort Dodge, Iowa, at 8 P. M.; President J. E. Van Liew in the chair; R. W. Crum, Secretary; and present, also, 19 members and 4 guests.

The minutes of the First Annual Meeting, held in Des Moines, Iowa, on November 20th, 1919, were read and approved.

The report of the Special Committee on Co-operation of Engineering Societies and Clubs in Iowa was presented by Mr. J. H. Dunlap, in the form of minutes of a conference on affiliation of engineering clubs and societies, held on January 9th, 1920, at the call of the Committee.

On motion, duly seconded, the plan was approved in spirit and extent, the representation of the Association at the organization meeting of the Council was fixed as one delegate for each fifteen members or fraction thereof, and the changes in the plan recommended by the Committee were approved.

On motion, duly seconded, the President was instructed to appoint four representatives from the Association to the conference of delegates of the Iowa Engineering Clubs and Societies to be held on February 20th, 1920, at Fort Dodge, Iowa.

President Van Liew subsequently appointed the following members of the Association as such delegates: Messrs. W. G. Raymond, Chairman, W. J. Schlick, H. S. Williams, and C. H. Currie.

The report of the Special Committee on Relations between Local Associations and the American Society of Civil Engineers, was presented by President Van Liew.

A report on the Annual Meeting of the Society was presented by Anson Marston, Director from District No. 7.

The Secretary was instructed by President Van Liew to inquire of the Secretary of the Society if it be the wish of the Board of Direction that Local Associations take any action concerning applications for membership in the Society.

Adjourned.

Louisiana Association, Organized 1914.

A. T. Dusenbury, President; Eugene F. Deléry, Secretary, 602 Sewerage and Water Board Building, New Orleans, La.

The regular meetings of the Association are held at The Cabildo, New Orleans, La., on the first Monday of January, April, July, and October.

Nebraska Association, Organized 1917.

Clark E. Mickey, President; Homer V. Knouse, Secretary-Treasurer, 200 City Hall, Omaha, Nebr.

Regular meetings of the Association are held on the first Saturday of each month, except July and August, and at such places as may be appointed from time to time by the Executive Committee. The Annual Meeting is held in Lincoln, Nebr., on the second Friday in January.

Visiting members of the Society are especially urged to communicate with the Secretary when in the city.

New York Section, Organized 1920.

Robert Ridgway, President; Lewis D. Rights, Secretary, 256 Broadway, New York City.

The Annual Meeting is held in May. The times and places of other meetings are not fixed, but this information will be furnished on application to the Secretary.

(Abstract of Minutes of Meeting)

March 31st, 1920.—The meeting was called to order at the Engineering Societies Building, at 8.35 P. M.; President Robert Ridgway in the chair; Lewis D. Rights, Secretary; and present, also, 70 members and 39 guests.

The minutes of the meeting of February 18th, 1920, were read and approved.

The President made a statement concerning the formation of the New York Section and its aims and purposes, and the Treasurer reported the membership to be 192.

President Ridgway ann unced that the Annual Meeting of the Section would be held on May 12th, 1920, and suggested the appointment of a Nominating Committee to nominate officers for the ensuing year.

Mr. Thomas C. Desmond offered a resolution as to the method of appointing a Nominating Committee, which, after discussion and amendment by Messrs. John A. Bensel and Richard S. Buck, was adopted by the meeting.

At the call of President Ridgway for nominations, the following names were designated: Messrs. Bensel, Brown, Buck, Castle, Gilman, Holland, Lavis, Mehren, and Turner.

On motion, duly seconded, the nominations were closed, and President Ridgway appointed Messrs. C. Raymond Hulsart, William G. Grove, and J. E. Beswick as Tellers to canvass the ballots for the Nominating Committee.

Lt.-Col. George D. Snyder, of the 22d Engineers, N. G. N. Y., read a letter asking for co-operation in recruiting that organization. On motion, duly seconded, the President was instructed to appoint a committee of three to co-operate with Col. Snyder in this matter.

Arthur P. Davis, President of the Society, addressed the meeting briefly on the progress of the Society.

An informal discussion on "A Bill for Licensing Engineers in New York" was opened by Mr. Clifford M. Holland, who was followed by Messrs. John A. Bensel, representing the Albany Society of Engineers, Allen Hazen, Richard S. Buck, A. D. Flinn, T. Kennard Thomson, Fred Lavis, Frederick Wilcock, George A. Orrok, Leonard D. Smith, of the American Association of Engineers, and William G. Grove. President Ridgway presented a letter from E. P. Goodrich, M. Am. Soc. C. E., on the subject.

On motion, duly seconded, the following resolution was adopted:

"That it is the expression of opinion of this meeting that engineers should be licensed in this State."

On motion, duly seconded, a resolution was adopted instructing the President to appoint a committee of three to wait on the State Legis-

lature, to acquaint it with the fact that the Section approved Bill No. 1258, and to urge the passage of such bill. President Ridgway subsequently appointed Messrs. Bensel, Buck, and Holland as such Committee.

Mr. J. P. J. Williams outlined briefly the important points of difference between the New York bill and that suggested as a model bill by Engineering Council.

The report of the Tellers appointed to canvass the ballot for the Nominating Committee was presented, and Messrs. Holland, Turner, Mehren, Castle, and Lavis were declared elected as the Nominating Committee, the Committee to select its own Chairman. Mr. Castle requested the members of the Section to make suggestions of names for candidates for officers to the Nominating Committee.

Adjourned.

Northwestern Association, Organized 1914.

Ralph D. Thomas, President; W. N. Jones, Secretary, City Engineer's Office, City Hall, Minneapolis, Minn.

The meetings of the Association are held bi-monthly, alternating between St. Paul and Minneapolis, on the third Friday of each month. Information as to the time and place of such meetings will be furnished on application to the Secretary.

Philadelphia Association, Organized 1913.

S. M. Swaab, President; Henry T. Shelley, Secretary, 416 City Hall, Philadelphia, Pa.

The regular meetings of the Association are held at the Engineers' Club of Philadelphia, 1317 Spruce Street, on the first Monday in January, April, and October, the last being the Annual Meeting. Special meetings are also held, in order to provide an opportunity for members to take a more active part in the work of the Association.

Pittsburgh Association, Organized 1917.

Morris Knowles, President; Nathan Schein, Secretary-Treasurer, 426 City-County Building, Pittsburgh, Pa.

The Annual Meeting of the Association is held on the first Monday in October. The time and place of other meetings are not fixed, but this information will be furnished on application to the Secretary.

Portland (Ore.) Association, Organized 1913.

J. C. Stevens, President; C. P. Keyser, Secretary, 318 City Hall, Portland, Ore.

The Annual Meeting of the Association is held on the second Friday in January. Other meetings are called by the President and are usually convened on Friday evenings. The place is not fixed, but this information may be obtained on application to the Secretary. All members of the American Society of Civil Engineers are cordially invited to attend the meetings.

(Abstract of Minutes of Meeting)

March 1st, 1920.—The meeting was called to order at the University Club, at 8 P. M.; President J. C. Stevens in the chair; C. P. Keyser, Secretary; and present, also, 21 members and 2 guests.

The minutes of the Annual Meeting, January 9th, 1920, were read and approved.

President Stevens announced that the members of the Board of Direction of the Association meet regularly at lunch at the University Club on the second and fourth Mondays of each month, and invited all members of the Association to attend these luncheons and make suggestions on matters discussed by the Board. He also reviewed briefly the action taken at such meetings since the Annual Meeting.

E. B. Thomson, Chairman of the Committee on the Formation of a Local Technical Council, reported that, at a meeting of delegates on February 20th, 1920, a constitution for the Oregon Technical Council had been adopted, which he offered as a Final Report of his Committee. On motion, duly seconded, the report was adopted and the Committee discharged.

On motion, duly seconded, the Board of Direction was empowered to appoint representatives of the Association to the Oregon Technical Council.

Mr. G. C. Mason explained the objects of an Industrial Disputes Commission which has been instituted by the National Rotary Clubs and is to be made up of ten representatives from organizations of the employer and employee classes, and moved that the Association appoint a representative to serve on that Commission, which motion, having been duly seconded, was carried.

The attention of the meeting was called to reports of un-American utterances on the part of a member of the Engineering Staff of the Faculty of the Oregon Agricultural College, and led to a discussion as to how far the Society or any of its Local Associations should go in interfering with the liberties of teachers on questions of morals or politics. On motion, duly seconded, the President was instructed to appoint a committee of three to investigate the charges against the faculty member in question and report back to the Association.

Mr. Mason, as member of the Development Committee from this District, made an appeal for a full vote on the Questionnaire sent out by the Society, on the subject, and Director Henny reported on events at the Annual Meeting of the Society, supplementing Mr. Mason's appeal for a full vote on the Questionnaire as an expression of the opinion and feeling of the members of this District on the work of the Development Committee.

The Secretary read a communication from Secretary Hunt relative to local items of interest for publication in the *Proceedings* of the Society, and it was stated that such matter would emanate from the Board of Direction.

Mr. Henny reported that he had interviewed all the Senators and Representatives from Oregon in regard to the Jones-Reavis Bill and that all of them were in favor of it.

Mr. J. P. Newell, President of the City Planning Commission, then addressed the meeting on "Zoning as Worked Out for the City of

Portland, and the Pending Zoning Ordinance". It was moved that the Association go on record as favoring the Zoning Ordinance as it stands and urge its immediate passage on the City Council, and the Chairman appointed Messrs. Dieck and Reed as a committee to draft a resolution to the Mayor and City Council embodying this motion.

Adjourned.

St. Louis Association, Organized 1888 (Constitution Approved by Board, 1914).

Edward E. Wall, President; C. W. S. Sammelman, Secretary-Treasurer, 300 City Hall, St. Louis, Mo.

The Annual Meeting of the Association, for the election of officers and for the transaction of business, is held on the fourth Monday in November. Two meetings each year, for the presentation and discussion of technical papers, are held in the Auditorium of the Engineers' Club of St. Louis and are open to members of the Associated Societies. Other "get-together" meetings are held regularly for dinner or luncheon on the fourth Monday of each month except July, August, and November.

San Diego Association, Organized 1915.

W. C. Earle, President; R. C. Wueste, Secretary-Treasurer, Bonita, Cal.

Seattle Association, Organized 1913.

John L. Hall, President; Bertram D. Dean, Secretary, 1711 Ravenna Boulevard, Seattle, Wash.

The regular meetings of the Association, with luncheon, are held at the Engineers' Club, Arctic Building, Third Avenue and Cherry Street, at 12.15 P. M., on the last Monday of each month. Informal luncheons are also held at 12.15 P. M., every Monday at the Engineers' Club.

Special evening meetings are held from time to time for the purpose of discussing important topics, and information concerning these meetings may be had by addressing the Secretary. All members in any grade of the American Society of Civil Engineers are cordially invited to attend the meetings when in the vicinity, and, if located in this District for any length of time, their membership in the Association will be appreciated.

(Abstract of Minutes of Meeting)

March 2d, 1920.—The meeting was called to order at 12.45 P. M., at the Masonic Club; President John L. Hall in the chair; Bertram D. Dean, Secretary; and present, also, 13 members.

The minutes of the Annual Meeting were read and approved.

The President read extracts from a letter from Professor A. H. Fuller relative to the Annual Meeting of the Society and particularly to the report of the Development Committee.

A verbal report of the work of the Committee on Associated Industries was made by Chauncy Wernecke, Chairman, and, on motion, duly seconded, the Committee was discharged.

It was moved and seconded, that the President be instructed to prepare and send out to all members of the Association a circular urging them to vote at as early a date as possible on the "Questionnaire" on the report of the Development Committee. After discussion by Messrs. Mogensen, Wernecke, and Warrack, the motion, duly seconded, was carried unanimously.

On motion, duly seconded, President Hall and Mr. T. E. Phipps were elected as representatives of the Association to the Joint Council of Engineering Societies.

On the suggestion of Mr. J. B. Warrack that the Association go on record as advocating the appointment by the new Mayor of Seattle of an engineer to fill any vacancy occurring in the Board of Public Works, the President was authorized, on motion, duly seconded, to appoint a committee to present the views of the Association to the new Mayor regarding these appointive offices. President Hall appointed Messrs. Jacobs, Wernecke, and Phipps as such committee.

Adjourned.

Southern California Association, Organized 1914.

W. K. Barnard, President; Floyd G. Dessery, Secretary, 514 Central Building, Los Angeles, Cal.

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular monthly meetings on the second Wednesday of each month, the December meeting being the Annual Meeting.

Informal luncheons in connection with the Joint Technical Societies of Los Angeles are held at 12.15 P. M., every Thursday at the Broadway Department Store Café.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

Spokane Association, Organized 1914.

Alfred D. Butler, President; Charles E. Davis, Secretary-Treasurer, 401 City Hall, Spokane, Wash.

The regular meetings of the Association are held on the second Friday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Visiting members are invited to attend the meetings.

Texas Association, Organized 1913.

Hans Helland, President; E. N. Noyes, Secretary, Deere Building, Dallas, Tex.

Utah Association, Organized 1916.

A. B. Villadsen, President, 304 Dooly Bldg., Salt Lake City, Utah.

The Annual Meeting of the Association is held on the first Wednesday in April. The time of other meetings is not fixed, but this information will be furnished on application to the President.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcome in the Reading Rooms and at the meetings of many engineering societies in all parts of the world. A list of such societies will be found on pages 42 and 43 of the Year Book of the Society for 1920.

Upon request by its Board of Trustees, the Engineering Societies of Wisconsin, Madison, Wis., is to be added to the above mentioned list, and its members are accorded the usual courtesies and privileges of the Headquarters of the Society.

NEW BOOKS*

(From March 1st to March 31st, 1920)

The statements made in these notices are taken from the books themselves, and this Society is not responsible for them.

DONATIONS TO ENGINEERING SOCIETIES LIBRARY

ELECTRIC OSCILLATIONS AND ELECTRIC WAVES:

With Application to Radiotelegraphy and Incidental Application to Telephony and Optics. By George W. Pierce. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1920. 517 pp., diagrams, tab., 9 x 6 in., cloth. $5.00.

This book is designed to present a mathematical treatment of some of the fundamentals of the theory of electric oscillations and electric waves. In the selection of material, the author has given first consideration to that which is particularly applicable to radiotelegraphy, yet he hopes that, as the electromagnetic theory involved in radiotelegraphy is also fundamental to optics, telephony, and power transmission, his work will be useful to students of these subjects.

ELECTRIC LIGHTING.

By Olin Jerome Ferguson. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1920. 243 pp., illus., diagrams, tab., 9 x 6 in., cloth. $2.50.

Although a number of excellent books exist which cover certain portions of the field included in the title of this volume, the author believes that there is need for a work giving a well-balanced presentation of fundamentals, with principles and practice explained throughout. This need he has tried to meet with a textbook of moderate size.

NOTES ON MAGNETISM:

For the Use of Students of Electrical Engineering. By C. G. Lamb. Cambridge, England, University Press, 1919. 94 pp., 55 illus., 9 x 5 in., paper. (Gift of G. P. Putnam's Sons.)

The author presents an outline of those essential parts of magnetic theory which a student of electrical engineering requires in order to read ordinary technical textbooks with intelligence. The book is based on the course at Cambridge University.

ARMATURE WINDING AND MOTOR REPAIR.

By Daniel H. Braymer. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 515 pp., illus., tab., 8 x 6 in., cloth. $3.00.

This book does not discuss the subject from the point of view of theory or design, but is a compilation of practical methods used by repair men and armature winders. The methods selected are those which represent the best practice in repair shops of average size and are given in detail.

MENSURATION FOR MARINE AND MECHANICAL ENGINEERS:

(Second and First-Class Board of Trade Examinations.) By John W. Angles. Lond. and N. Y., Longmans, Green and Co., 1919. 162 pp., illus., diagrams, 7 x 5 in., cloth. $1.75.

This textbook is intended to enable students to pass the examinations of the Board of Trade (Great Britain) for licenses as marine engineers, but will be useful, the author hopes, to engineering students in other lines. A feature is made of fully solved examples, illustrating the practical applications of the theoretical principles involved in the text.

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* Unless otherwise specified, books in this list have been donated by the publishers.

MOTOR VEHICLE ENGINEERING:

Engines (for Automobiles, Trucks, and Tractors). By Ethelbert Favary. Second Edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 333 pp., illus., plates, tab., 9 x 6 in., cloth. $3.50.

The author states that many chapters of this edition have been entirely rewritten, that the practical data have been brought up to date, and that the work has been generally revised. The book treats of automobile engines and is intended to give a concise, simple statement of the everyday information needed by automotive engineers.

FLOW AND MEASUREMENT OF AIR AND GASES.

By Alec B. Eason. Lond., Charles Griffin & Co., Ltd.; Phila., J. B. Lippincott Co., 1919. 252 pp., illus., diagrams, tab., 9 x 6 in., cloth. 25 shillings.

The engineering problems investigated in this book arise in connection with pneumatic tubes and compressed air, gas lighting, and ventilating systems. The author has investigated, by study of the literature and by experiment, the friction of gases and the coefficient of friction in pipes, the question of suitable meters for gas and air, and the working of pneumatic tubes, and has attempted to co-ordinate the results of the various tests and formulas, so that the reason for variations may be appreciated. Full references to the sources of information are given.

THE DESIGN OF SCREW PROPELLERS:

With Special Reference to Their Adaptation for Aircraft. By Henry C. Watts. Lond. and N. Y., Longmans, Green and Co., 1920. 340 pp., illus., charts, diagrams, plate, tab., 9 x 6 in., cloth. $8.00.

During the war, the author was in charge of technical work in connection with propellers for aircraft at the Admiralty and Air Ministry of Great Britain, and many of the propellers used were designed by him or under his supervision. This volume records the results of his experience. It is intended as a guide to practical design and gives slight attention to mathematical theory of the behavior of screw propellers. A chapter on the design of windmills is included.

DESIGN AND CONSTRUCTION OF HEAT ENGINES.

By William E. Ninde. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 704 pp., illus., diagrams, tab., 9 x 6 in., cloth. $6.00.

The object of this book is to supply in one volume the material most essential to the well-equipped, independent designer of heat engines, and to give this material in the form most convenient for use in classroom and practical work by a separate treatment of the different phases of the subject. The book is the outgrowth of twenty years' experience, and a study of the literature, drawings, and practical data. The volume is confined to the steam engine, steam turbine, and internal combustion engine. Contents: The Heat Engine; Thermodynamics; Friction and Lubrication; Power and Thrust; Mechanics; Machine Design.

AMERICAN MACHINISTS' HANDBOOK:

A Reference Book of Machine Shop and Drawing-Room Data, Methods, and Definitions. By Fred H. Colvin and Frank A. Stanley. Third Edition, Thoroughly Revised and Enlarged. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 758 pp., illus., diagrams, tab., 7 x 4 in., flexible cloth. $4.00.

This pocket-book has been prepared to present in convenient form such data as will be of value to practical men in the various branches of machine work. The present edition has been thoroughly revised. Seventy-seven pages have been added and much other new material included by the elimination of less important matter from the previous edition.

METALLOGRAPHY:

Part I, Principles of Metallography. By Samuel L. Hoyt. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 256 pp., illus., diagrams, tab., 9 x 6 in., cloth. $3.00.

This volume, the first of a series of three based on the author's lectures at the University of Minnesota, deals with general principles and with some of the more important methods used in general investigations in the metallographic laboratory. Future volumes will discuss the metallography of the metals and alloys and the applications of metallography to the metallurgical and engineering industries.

MANUAL OF CYANIDATION.

By E. M. Hamilton. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 277 pp., illus., tab., 7 x 5 in., flexible cloth. $3.00.

The aim of this book is to provide in a handy sized volume a compendium of all the ascertainable facts concerned with the cyanide process that may have a practical bearing on testing an ore, planning the flow sheet, and operating the plant when erected. Purely theoretical questions have been left in the background.

L'OR: PROSPECTION—GISEMENT—EXTRACTION.

By Georges P. Proust. Paris, Gauthier-Villars et Cie, 1920. 319 pp., illus., 9 x 6 in., paper. 10 francs.

This work by a French mining engineer is a summary account of the mining and metallurgy of gold. After an introductory chapter on mineralogy, the author treats of prospecting and testing, exploitation, preparatory treatment, cyaniding, mining costs, and alluvial mining. A chapter of advice on hygiene and diet for residents in tropical lands is included, and also a mineralogical lexicon. The book is evidently intended for engineers engaged in the development of new mines.

MICROSCOPIC EXAMINATION OF THE ORE MINERALS.

By W. Myron Davy and C. Mason Farnham. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 154 pp., illus., tab., 9 x 6 in., cloth. $2.50.

The authors present a table for determining the identity of ore minerals by means of the reflecting microscope and micro-chemical tests, for the use of mineralogists, geologists, and engineers. In addition to the table, instruction in polishing and examining specimens and in photomicrography is given, as well as a collection of supplementary tests.

MINERAL RESOURCES OF ARMENIA AND ANATOLIA.

By Hagop A. Karajian. N. Y., Armen Technical Book Co., 1920. 211 pp., illus., maps, 9 x 6 in., cloth. $3.00.

This volume is a summary of the knowledge of the mineral resources and the present state of the mining industry in Armenia and Anatolia, accompanied by a survey of the geology of the region. A number of sketch maps and a bibliography are included.

THE IRON HUNTER.

By Chase S. Osborn. N. Y., The Macmillan Co., 1919. 316 pp., plates, portraits, 8 x 5 in., cloth. $2.00.

Ex-Governor Osborn of Michigan has been closely associated with the development of the iron ores of the Northwest and of Canada from the early "Eighties" to the present. It has been his hobby to visit all the commercial iron fields of the world. His autobiography is an interesting, unconventional account of his life as a journalist, prospector, and statesman, full of information about men and affairs during the early mining days in Wisconsin and Michigan.

GRAPHIC PRODUCTION CONTROL.

By C. E. Knoeppel, Assisted by Various Members of the Author's Firm and Staff. N. Y., The Engineering Magazine Co., 1920. 477 pp., illus., diagrams, charts, 9 x 6 in., cloth. $6.00.

This treatise on the use of graphic charts in shop control is intended to provide a complete description of the proper methods of making graphic charts and of applying them to industrial problems. The general principles of graphic control, the preliminaries of its installation, the practical operation of the system, etc., are discussed in detail.

THE ORGANIZATION OF INDUSTRIAL SCIENTIFIC RESEARCH.

By C. E. Kenneth Mees. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 175 pp., 8 x 6 in., cloth. $2.00.

This volume is a contribution to the current discussion of the relation of scientific research to industry. The author is concerned with a study of the best methods of organizing research work for industrial purposes and of the conditions under which such work should be conducted, and has made an effort to give definite suggestions on these points. The book is intended for those who plan to undertake research work rather than as an exposition of its theoretical advantages. Contents: Types of Research Laboratories; Co-operative Laboratories; Position of the Research Laboratory in an Industrial Organization: Internal Organization of Industrial Research Laboratories; Staff of a Research Laboratory; Building and Equipment of the Laboratory; Direction of the Work: Design of a Research Laboratory for a Specific Industry.

STATISTICS IN BUSINESS:

Their Analysis, Charting, and Use. By Horace Secrist. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 137 pp., illus., diagrams, maps, tab., 8 x 6 in., cloth. $1.75.

This volume has been prepared to serve as a handbook for executives in the application of business statistics to problems which arise. It aims to present briefly and concretely the reasons why statistics should be used in business analysis and to illustrate how and with what effect they may be applied to the solution of business problems. The discussion is of a practical nature. Especial attention is given to the use of charts and graphs. Examples of good and bad usage are given.

INTRODUCTION TO GENERAL CHEMISTRY.

By Herbert N. McCoy and Ethel M. Terry. Second Edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 648 pp., illus., 9 x 6 in., cloth. $3.00.

This text-book is intended as an introduction to general chemistry for use by college freshmen and is based on the course in the University of Chicago. The aim has been to present a continuous, connected story in teachable form, without unnecessarily extensive descriptive and numerical data. In this edition misprints have been corrected and a chapter on metallurgy has been added.

AMERICAN CIVIL ENGINEERS' HANDBOOK.

Editor-in-Chief, Mansfield Merriman. Fourth Edition. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1920. 1955 pp., tab., 7 x 4 in., flexible cloth. $6.00.

The fourth edition of this well-known reference work follows the plan of the previous editions and is the achievement of a board of eighteen associate editors, under the direction of Prof. Merriman. The volume has been thoroughly revised, a collection of mathematical tables included, and new sections on electric railways, irrigation, and drainage have been added. Nearly 400 pages have been added to the work. Because of the comprehensiveness of the book, it has been entitled a "Handbook" instead of, as formerly, a "Pocket Book".

WHITE-LEAD: ITS USE IN PAINT.

By Alvah Horton Sabin. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1920. 133 pp., tab., 8 x 5 in., cloth. $1.25.

In his small work Dr. Sabin has provided a brief, non-technical account of the subject for the instruction and guidance of those whose need and use of white lead prompts them to seek knowledge about it of a simple but reliable sort. The various methods of making white lead are given, together with the properties of the usual substitutes, methods of mixing paint for different purposes, etc.

DAVISON'S SILK TRADE:

A Directory of the Silk Manufacturers of the United States and Canada including Silk Dyers, Finishers, and Printers, Manufacturers' Agents, City Offices and Salesrooms of Silk Mills, Dealers in Raw, Thrown, Spun and Artificial Silk, Waste, Cotton, Tinsel and Worsted Yarns. Twenty-fifth Annual Edition. N. Y., Davison Publishing Co., 1920. 782 pp., 7 x 5 in., flexible cloth, pocket edition. $3.00.

The scope of this directory is fully shown by the title. The directory of manufacturers appears in three sections, classified alphabetically, geographically, and by the kind of goods made. The other sections are arranged geographically or alphabetically, as seems more expedient. The volume is of pocket size and provided with a marginal index.

HENDRICKS' COMMERCIAL REGISTER OF THE UNITED STATES

For Buyers and Sellers. Twenty-eighth Annual Edition. N. Y., S. E. Hendricks Co., Inc., 1919-20. 2541 pp., 10 x 8 in., cloth. $12.50.

This new edition, like its predecessors, is devoted to the electrical, engineering, hardware, iron, mechanical, mill, mining, architectural, quarrying, chemical, railroad, steel, contracting and kindred trades. The firms included are listed alphabetically and by products. A subject index and an index of trade names are also included.

THOMAS' REGISTER OF AMERICAN MANUFACTURERS

And First Hands in All Lines. Eleventh Edition. N. Y., Thomas Publishing Co., 1920. 12 x 9 in., cloth. $15.00.

The eleventh edition of this widely known directory has been revised and enlarged to the size of 4 500 pages. It covers manufacturers and dealers in all classes of materials, and contains a classified list of manufacturers with indications of their approximate ratings, an alphabetical list of the more important firm names, and a list of brand or trade names of manufactured articles. Contents: Finding List and Index; Lists of Manufacturers Classified According to Business; Manufacturers of the United States Arranged Alphabetically; Leading Trade Names, Brands, etc.; Banks, Boards of Trade and other Commercial Organizations; Leading Trade Papers; Manufacturers' Representatives; Export and Import Houses; Steamship Lines and Forwarding Agents, Banks, etc.; Overseas Importers, Merchants, etc.

MEMBERSHIP

(From March 5th to April 5th, 1920)

ADDITIONS

MEMBERS

		Date of Membership.
ADAMS, WILLIAM HENRY. Cons. Engr.; Chairman, Inland Waterways Committee, Detroit Board of Commerce, Vinton Bldg., Detroit, Mich.	Assoc. M. M.	April 2, 1912 Jan. 20, 1920
ALLEN, EUGENE YORKE. Valuation Engr., C. R. R. of N. J. and P. & R. Ry., 143 Liberty St., New York City	Assoc. M. M.	Dec. 6, 1905 Mar. 9, 1920
BENEDICT, HAROLD WILLOUGHBY. Asst. Engr., Dept. of State Engr., 292 Fifth Ave., Troy, N. Y.	Assoc. M. M.	Jan. 3, 1911 Mar. 9, 1920
BILYEU, CHARLES SMITH. Asst. to Pres. and Structural Engr., Gulick-Henderson Co., Herald Square Bldg., New York City	Jun. Assoc. M. M.	Dec. 1, 1908 Dec. 31, 1913 Jan. 20, 1920
BLACKBURN, THOMAS BROGDEN. 722 Bixel St., Los Angeles, Cal.		Oct. 14, 1919
CHENERY, CHRISTOPHER TOMPKINS. McLachlen Bldg., Washington, D. C.		Mar. 9, 1920
CLARK, ELMER WHITE. Asst. Engr., Chf. Engr.'s Dept., P. R. R., 1155 Liberty Ave., Pittsburgh, Pa.		Mar. 9, 1920
FERGUSON, JOHN WILLIAM. Dist. Plant Engr., Oregon Dist., U. S. Shipping Board, Emergency Fleet Corporation, 537 Northwestern Bank Bldg., Portland, Ore.		Mar. 9, 1920
HAGERMAN, HENRY LEHMBERG. With J. E. Sirrine, Box 1221, Greenville, S. C.		Mar. 9, 1920
HALE, HUGH ELLMAKER. Engr., Eastern Group, President's Conference Committee, Federal Valuation of the Railroads in the United States, 32 Nassau St., New York City		Mar. 9, 1920
HOLLAND, HOWARD KINGSBURY. Cons. Engr. (Holland, Ackerman & Holland), Lawrence Bldg., Ann Arbor, Mich.	Jun. Assoc. M. M.	June 1, 1909 Oct. 29, 1912 Mar. 9, 1920
HOLMES, HUGH BROWNING. Prin. Asst. Engr., Coverdale & Colpitts, 66 Broadway, New York City	Assoc. M. M.	Nov. 27, 1917 Mar. 9, 1920
HOWSON, ELMER THOMAS. Western Editor, *Railway Age*; Editor, *Railway Maintenance Engineer*, 750 Transportation Bldg., Chicago, Ill.	Assoc. M. M.	May 28, 1912 Mar. 9, 1920
KLYCE, BATTLE HARGROVE. (Klyce & Kackley), 721 Fourth and First National Bank Bldg., Nashville, Tenn.	Assoc. M. M.	June 30, 1911 Mar. 9, 1920

MEMBERS (*Continued*)

		Date of Membership.
KNEEDLER, DAVID HENRY LANE. In Chg., Reinforced Concrete Dept., Cramp & Co., 801 Denckla Bldg., Philadelphia, Pa.		Mar. 9, 1920
LARSEN, ALBERT. Div. Engr., Miami Conservancy Dist., Dayton, Ohio	Assoc. M. M.	Aug. 31, 1915 Mar. 9, 1920
LEIGH, WORD. Care, Gaston, Williams & Wigmore, Shanghai, China		Jan. 19, 1920
MACKENZIE, LEON RODERICK. Cons. Engr., Southern Surety Co., 8th Floor, Register & Tribune Bldg., Des Moines, Iowa	Assoc. M. M.	Sept. 12, 1916 Mar. 9, 1920
MCMILLAN, FRANKLIN R. Care, Turner Constr. Co., 244 Madison Ave., New York City	Assoc. M. M.	Sept. 11, 1917 Mar. 9, 1920
MATSUMOTO, TORATO. Care, Public Works Dept., Keelung, Formosa, Japan		Sept. 9, 1919
MELICK, NEAL ALBERT. Chf. Engr., Submarine Boat Corporation (Res., 484 Clifton Ave.), Newark, N. J.	Jun. Assoc. M. M.	Dec. 2, 1902 July 9, 1906 Mar. 9, 1920
MENDENHALL, HERBERT DRUMMOND. Lakeland, Fla.	Jun. Assoc. M. M.	Sept. 4, 1906 July 9, 1912 Mar. 9, 1920
NEWCOMB, WILLIAM TAFT. Engr., Amies Road Co., 710 Drake Bldg., Easton, Pa.	Assoc. M. M.	Feb. 6, 1912 Mar. 9, 1920
PYLE, FRED DALE. Project Mgr., Uncompahgre Valley Project. U. S. Reclamation Service, 718 North 5th St., Montrose, Colo.	Assoc. M. M.	Jan. 17, 1916 Mar. 9, 1920
RANDOLPH, ROBERT ISHAM. Secy. and Treas., Isham Randolph & Co., 208 South La Salle St., Room 1133, Chicago, Ill.	Jun. Assoc. M. M.	July 1, 1909 Nov. 1, 1910 Mar. 9, 1920
RICHARDS, ARTHUR. County Bridge Engr., County Surveyor's Office, Columbus, Ohio.	Jun. Assoc. M. M.	Jan. 4, 1910 Sept. 2, 1914 Mar. 9, 1920
RUGGLES, ARTHUR VALENTINE. Engr. of Constr. and Surveys, Water Dept., Cleveland, Ohio	Assoc. M. M.	April 30, 1912 Mar. 9, 1920
RUGGLES, CHARLES HERMAN. Cons. Engr.; Chf. Engr., Palm Beach & Gulf Constr. Co., West Palm Beach, Fla.	Assoc. M. M.	Sept. 2, 1914 Mar. 9, 1920
SACKETT, ARTHUR JOHNSON. Care, Mason & Hanger Co., 52 Vanderbilt Ave., New York City	Jun. Assoc. M. M.	Mar. 1, 1904 Nov. 4, 1914 Mar. 9, 1920
SCHINDLER, ANDREW D. Vice-Pres. and Gen. Mgr., Kings County Development Co., 805 Insurance Exchange Bldg., San Francisco, Cal.		Mar. 9, 1920
SCHMITT, FREDERICK E. Associate Editor, *Engineering News-Record*, 10th Ave. and 36th St., New York City (Res., 22 Carteret St., Montclair, N. J.)		Mar. 9, 1920

MEMBERS (*Continued*)

		Date of Membership.
SCHUTT ALFRED GEORGE. Architectural Engr.; Res., 764 Virginia Park, Detroit, Mich.	Assoc. M. M.	Sept. 2, 1914 Mar. 9, 1920
SWINDELLS, JOSEPH SPRINGER. Cons. Engr., 111 Broadway, Room 1110, New York City..	Jun. Assoc. M. M.	Feb. 2, 1897 Mar. 2, 1904 Mar. 9, 1920
TRACY, JOHN CLAYTON. Prof., Civ. Eng., and Head, Dept. of Civ. Eng., Yale Univ.; Cons. Engr.; Director, New Haven Chamber of Commerce, 345 Winthrop Ave., New Haven, Conn.		Mar. 9, 1920
WELLS, FRANCIS SPINNER. 25 Fairview Terrace, Malden, Mass.		Mar. 9, 1920
WHITSIT, LYLE ANTRIM. 226½ Peachtree St., Atlanta, Ga.	Jun. Assoc. M. M.	Oct. 31, 1905 Sept. 6, 1910 Mar. 9, 1920
WILLIS, THOMAS LEROY. City Engr., Room 21, City Hall, New Orleans, La.		Mar. 9, 1920

ASSOCIATE MEMBERS

ANSCHUETZ, OTTO WILLIAM JULIUS. With E. B. Fay (Res., 3614 Arsenal St.), St. Louis, Mo.	Jun. Assoc. M.	May 2, 1911 Mar. 9, 1920
ATWATER, ALBERT WORTHINGTON. Engr., Arthur G. McKee & Co., 2422 Euclid Ave. (Res., 1464 Cordova Ave., Lakewood), Cleveland, Ohio.		Sept. 9, 1919
BACHMAN, HOWARD FINK. Chf. of Material and Stores, Bethlehem Steel Co., 802 West Broad St., Bethlehem, Pa.		Nov. 25, 1919
BERNARD, MERRILL MONFORT. City Engr., Crowley, La.		Mar. 9, 1920
BIRNER, ISADOR LEON. Chf. Engr. and Technical Mgr., The Refinite Co., Refinite Bldg., Omaha, Nebr.		Mar. 9, 1920
BOND, ARTHUR HAZARD. Res. Engr., Monks & Johnson, 99 Chauncy St., Boston, Mass.		Mar. 9, 1920
BROWN, PERCY DALLES. Asst. Engr., P. R. R., Broad St. Station, P. R. R., Philadelphia, Pa.		Mar. 9, 1920
BRUTON, PHILIP GILSTRAP. 2d Lieut., A. S. A. (P.), U. S. A., Bureau of Aircraft Production, 2050 Elmwood Ave., Buffalo, N. Y.	Jun. Assoc. M.	Sept. 10, 1918 Mar. 9, 1920
CALLAN, JOHN ALBERT CHARLTON. 1305 West 22d St., Austin, Tex.		Mar. 9, 1920
CAMERON, DONALD EUGENE AMES. Archt. and Engr. (Robinette-Bruyere-Cameron), 755 Spitzer Bldg. (Res., 1025 Grand Ave.), Toledo, Ohio.		Mar. 9, 1920
CAREY, GEORGE JOSEPH FRANCIS. Care, Compania Transmarina de Cuba, Matanzas, Cuba.		Jan. 19, 1920

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
CONSOER, ARTHUR WILLIAM. (Consoer Eng. Co.), 1657 Monadnock Blk., Chicago, Ill.		Mar. 9, 1920
COYKENDALL, CLAUDE CARLISLE. Engr., Road Management, Iowa State Highway Comm., 808 Park Ave., Ames, Iowa		Mar. 9, 1920
DU BOIS, FRANCIS WHEELOCK. 232 Elmhurst Ave., Detroit, Mich.		Oct. 14, 1919
DU BOSE, FRANK FITZPATRICK. With Potts & Prentice, 1410 Amicable Bldg., Waco, Tex.		Mar. 9, 1920
ELTON, RICHARD LEECH. Constr. Engr. and Supt., Builders Material Supply Co., 3330 Tracy Ave., Kansas City, Mo.		Mar. 9, 1920
EMERSON, LEWIS AZRO. (Tomlinson Eng. Co.), 1002 Loan and Exchange Bldg., Columbia, S. C.		Mar. 9, 1920
FARIS, ORVILLE ALVA. Box 497, Boise, Idaho		Mar. 9, 1920
GERAGHTY, LEO MATTHEW. 42 Prichard Ave., West Somerville, Mass.		Oct. 14, 1919
GOODWIN, ALBERT EDWARD. 505 Hill St., Sewickley, Pa.		Mar. 9, 1920
HAMMILL, HAROLD BERNARD. 2032 Parker St., Berkeley, Cal.	Jun.	April 2, 1913
	Assoc. M.	Mar. 9, 1920
HARBAUGH, ROSS ANDERSON. Estimate Engr., Pittsburgh Filter & Eng. Co., 202 West 3d St., Oil City, Pa.		Mar. 9, 1920
HARRIS, JOHN KELLAR. (Harris & Cole), 401 South Oakland Ave., Sharon, Pa.		Mar. 9. 1920
HEWETT, MAURICE WILLIAM. Eng. Contr., William S. Hewett, 530 Metropolitan Bank Bldg., Minneapolis, Minn.	Jun.	Sept. 2, 1914
	Assoc. M.	Mar. 9, 1920
HOGG, JAMES OLIVER, JR. Estimator, Collins Bros., 536 Rialto Bldg., Kansas City, Mo.		Mar. 9, 1920
HURLEY, JOHN JAMES. Branch Mgr., Truscon Steel Co., Room 902, Mutual Home Bldg., Dayton, Ohio	Jun.	April 16, 1918
	Assoc. M.	Mar. 9, 1920
JAHN, NICHOLAS FIRTH. Contr. (Jahn & Bressi), 710 New York Bldg., Seattle, Wash.		Mar. 9, 1920
JONES, OWEN ROBERT. 520 West 131st St., New York City.		Nov. 25, 1919
JOWERS, GILES MATTHEW. Special Engr., International Boundary Comm., Box 1106, Del Rio, Tex.		Mar. 9, 1920
LAYER, HUGO. (The Shannon Constr. Co.), 1351 South Main St., Akron, Ohio		Jan. 19, 1920
LOWE, HERBERT EDWARD. Engr., Emergency Fleet Corporation, 960 Ventura Ave., Berkeley, Cal.		Jan. 19, 1920
MCAVOY, JAMES PATRICK. Asst. Engr., Valuation Dept., The Delaware & Hudson Co., Room 1003, Delaware & Hudson Bldg., Albany, N. Y.		Mar. 9, 1920

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
McNear, George Plummer, Jr. Care, Guaranty Trust Co. of New York, 140 Broadway, New York City		Mar. 9, 1920
Martius, Frederick Traugott. Engr. in Chg. of Dept., Fuel Oil Storage System, National Boiler Washing Co., Railway Exchange, Chicago, Ill		Mar. 9, 1920
Moone, Melvin Lyman. Asst. City Engr., City Engr.'s Office, Lansing, Mich	Jun. Assoc. M.	Jan. 6, 1915 Mar. 9, 1920
Morss, Foster Gilbert. 606 News Bldg., Salt Lake City, Utah		Mar. 9, 1920
Noice, Blaine. 5436 Carlton Way, Los Angeles, Cal		Mar. 9, 1920
Norton, James William. County Road Engr., Nicholas County, 101 East Chestnut St., Carlisle, Ky		Mar. 9, 1920
Nygren, Frank Harry. Chf. Engr., A. E. Norton, Inc., 105 West 40th St., New York City (Res., 1803 Ave. Q, Brooklyn, N. Y.)		Mar. 9, 1920
Ogden, Chester White. 507 West End Ave., New York City		Mar. 9, 1920
Opper, George Lionel. Asst. Engr., Marr, Green & Co., 464 South Harrison St., Kankakee, Ill		Jan. 19, 1920
Orr, George. Asst. Engr., Eng. Dept., City of Atlantic City, City Hall, Atlantic City, N. J		Mar. 9, 1920
Reynolds, Frank Louis. Vice-Pres., Fox, Reynolds Co., Inc., 81 East 125th St., New York City	Assoc. Assoc. M.	Nov. 26, 1918 Mar. 9, 1920
Reynolds, Ralph Whitney. 292 St. John's Pl., Apartment 50, Brooklyn, N. Y	Jun. Assoc. M.	Nov. 28, 1916 Mar. 9, 1920
Roberts, Harry Norman. Cons. Engr., City of Longview, and Cons. Engr., City of Henderson, Box 9, Longview, Tex		Mar. 9, 1920
Saigh, Nicholas A. Care, Const. Q. M., Camp Travis, San Antonio, Tex		Mar. 9, 1920
Semon, Edward Goodrich. Asst. Engr., William Russell Davis, 563 Third St., Albany, N. Y		Mar. 9, 1920
Seran, Harry A. Care, U. S. Coast and Geodetic Survey, Washington, D. C		Mar. 9, 1920
Shea, Chelius Hazel. Asst. Div. Engr., The Miami Conservancy Dist., R. R. 4, Piqua, Ohio	Jun. Assoc. M.	April 2, 1912 Mar. 9, 1920
Shurgar, Will Gerald. Cons. Engr., Box 611, Meridian, Miss		Mar. 9, 1920
Tews, Frank Charles. Care, Colfax, Hotel Colfax, Colfax, Wash		Mar. 9, 1920
Thomassen, Victor Gifford. Res. Engr., U. S. Steel Products Co., 11 rue Edouard VII, Paris, France		Jan. 19, 1920
Waldo, Willis Gersham. 230 Vine St., Chattanooga, Tenn		Mar. 9, 1920

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
WHITNEY, CHARLES SMITH. Chf. Engr., A. C. Eschweiler, 720 Goldsmith Bldg., Milwaukee, Wis.	Jun. Assoc. M.	Dec. 2, 1914 Mar. 9, 1920
WOHLFELD, NATHAN. 1910 Commerce St., Dallas, Tex.		Mar. 9, 1920
WOLCOTT, LESTER OREN. Civ. and Hydr. Engr., San Joaquin Light & Power Corporation (Res., 1560 Van Ness Ave.), Fresno, Cal.		Mar. 9, 1920
WYKKEL, LEO JOHN. Asst. Engr., Kalamazoo County Road Comm., 510 Walnut Court, Kalamazoo, Mich.		Jan. 19, 1920

ASSOCIATES

THORP, JOHN NOTMAN, JR. 631 East 22d St., Paterson, N. J.	Mar. 9, 1920

JUNIORS

BEDELL, FLOYD CARSON. U. S. Junior Engr., U. S. Engr. Office, 39 Whitehall St., Room 710, New York City.	Jan. 19, 1920
BLUNDON, JOSEPH PAUL. County Engr., Boone County Highway Dept.. Madison. W. Va.	Oct. 14. 1919
ELLEMAN, JOHN HAWKINS. The Engineer School, Camp A. A. Humphreys, Va.	Jan. 19, 1920
HAERTLEIN, ALBERT. Instr. in Civ. Eng., Harvard Eng. School, 309 Pierce Hall, Cambridge, Mass.	Mar. 9, 1920
HARTLINE, WILLIAM RAYMOND. With The Texas Co., 916 Texas Co. Bldg., Houston, Tex.	Jan. 19, 1920
HSUEH, CHO-PIN. Care, C. Y. Hou, 125 Dryden Rd., Ithaca, N. Y.	Mar. 9, 1920
KAISER, WILLIAM MARTIN. Traffic Mgr., Grant Smith Porter Ship Co., 695 Weidler St., Portland, Ore.	Jan. 19, 1920
NORDGREN, GEORGE ALVIN. 8023 Sangamon St., Chicago, Ill.	Mar 9, 1920
OLSON, LUTHER EMANUEL. Supt. of Constr., A. A. Lane Constr. Co., 1297 Jackson Ave., Lakewood, Ohio.	Nov. 25, 1919
SCHILLING, FRANK MARTIN. McHenry House, Bloomsburg, Pa.	Mar. 9, 1920
SPEIR, OSWALD, JR. Chf. of Party, San Joaquin Light & Power Corporation, Fresno, Cal.	Oct. 14, 1919

DEATHS

ATWOOD, JOHN ABIEL. Elected Member, January 3d, 1900; died February 29th, 1920.

BURBANK, GEORGE BARKER. Elected Member, July 4th, 1888; died February 29th, 1920.

HANSEN, ANDREW CHRISTIAN. Elected Member, October 4th, 1910; died February 9th, 1920.

HATCH, FREDERICK THOMAS. Elected Member, December 4th, 1889; died March 9th, 1920.

HAZLEHURST, GEORGE BLAGDEN. Elected Member, February 1st, 1888; died May 27th, 1919.

NORCROSS, ORLANDO WHITNEY. Elected Member, October 31st, 1911; died February 27th, 1920.

PARSONS, GEORGE WELLMAN. Elected Associate, September 3d, 1884; died August 15th, 1919.

RAYMOND, ALFRED. Elected Member, September 6th, 1910; died January 13th, 1920.

THOMPSON, ELLIS DUNN. Elected Member, February 1st, 1899; died February 9th, 1920.

Total Membership of the Society, April 5th, 1920,
9 441.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(March 1st to April 1st, 1920).

NOTE.—*This list is published for the purpose of placing before the members of this Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Journal,* Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Journal,* Eng. Inst. of Canada, Montreal, Que., Canada.
(6) *Journal,* Am. Inst. of Archts., Washington, D. C., 50c.
(7) *Gesundheits Ingenieur,* Munich, Germany.
(8) *Stevens Indicator,* Hoboken, N. J., 50c.
(9) *Industrial Management,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News-Record,* New York City, 15c.
(15) *Railway Age,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Electric Railway Journal,* New York City, 10c.
(18) *Railway Review,* Chicago, Ill., 15c.
(19) *Scientific American Monthly,* New York City, 10c.
(20) *Iron Age,* New York City, 20c.
(21) *Railway Engineer,* London, England, 1s. 2d.
(22) *Iron and Coal Trades Review,* London, England, 6d.
(24) *American Gas Engineering Journal,* New York City, 10c.
(25) *Railway Mechanical Engineer,* New York City, 20c.
(26) *Electrical Review,* London, England, 4d.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Royal Soc. of Arts, London, England, 6d.
(32) *Mémoires et Compte Rendu des Travaux,* Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil,* Paris, France, 1 fr.
(36) *Cornell Civil Engineer,* Ithaca, N. Y.
(40) *Zentralblatt der Bauverwaltung,* Berlin, Germany, 60 pfg.
(41) *Elektrotechnische Zeitschrift,* Berlin, Germany.
(42) *Journal,* Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées,* Paris, France.
(45) *Coal Age,* New York City, 15c.
(46) *Scientific American,* New York City, 15c.
(47) *Mechanical Engineer,* Manchester, England, 3d.
(48) *Zeitschrift,* Verein Deutscher Ingenieure, Berlin, Germany, 1, 60 m.
(49) *Zeitschrift für Bauwesen,* Berlin, Germany.
(50) *Stahl und Eisen,* Düsseldorf, Germany.
(53) *Zeitschrift,* Oesterreichischer Ingenieur und Architekten-Verein, Vienna, Austria, 70h.
(54) *Transactions,* Am. Soc. C. E., New York City, $16.
(55) *Mechanical Engineering:* Journal, Am. Soc. M. E., New York City, 35c.
(56) *Transactions,* Am. Inst. Min. and Metallurgical Engrs., New York City, $6.
(57) *Colliery Guardian,* London, England, 5d.
(58) *Proceedings,* Engrs.' Soc. of W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings,* American Water Works Assoc., Troy, N. Y.
(60) *Municipal and County Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Drop Forger,* Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 10c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Gas Journal,* London, England, 6d.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(69) *Eisenbau,* Leipzig, Germany.
(71) *Journal,* Iron and Steel Inst., London, England.
(71a) *Carnegie Scholarship Memoirs,* Iron and Steel Inst., London, England.

(72) *American Machinist*, New York City, 15c.
(73) *Electrician*, London, England, 18c.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(77) *Journal*, Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen*, Vienna, Austria, 1, 50m.
(80) *Tonindustrie Zeitung*, Berlin, Germany.
(83) *Gas Age*, New York City, 15c.
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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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Vol. XLVI. APRIL, 1920. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

HYDRAULIC-FILL DAMS

By Allen Hazen,* M. Am. Soc. C. E.

To be Presented May 5th, 1920.

Synopsis.

The hydraulic method of dam construction has great advantages, but too many dams built by it have failed.

As often built, the center of the dam is composed of a clay core completely water-tight but very wet as a result of the method of construction, and so completely water-tight that it is incapable of permitting its own drainage.

This soft core in the center of the dam exerts the pressure of a liquid of high specific gravity upon the toes and tends to push them out. This pressure seems to have been responsible for most of the failures of hydraulic-fill dams.

The method of placing the core commonly used results in an exceedingly fine-grained material, desirable from the standpoint of a water-tight dam; but it may be that extreme tightness is secured at the expense of stability.

To use the hydraulic method of dam construction successfully, it is necessary either to increase the toes until they are large and heavy enough successfully to resist the full fluid pressure of the core, or else

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

* New York City.

to handle the core material so that the finest particles are wasted, leaving only the larger ones, and in that way increasing the grain size to a point where drainage can be secured, while on the other hand remaining sufficiently impervious for practical purposes.

Methods of testing are described and an effort is made to analyze the conditions of stability.

The hydraulic-fill method of dam construction grew out of hydraulic mining. It was natural that a process conspicuously successful in mining on an enormous scale, and that moved material at very low unit costs, should find other applications.

The late James D. Schuyler and J. M. Howells, Members, Am. Soc. C. E., were pioneers in the application of hydraulic methods to dam construction. Mr. Schuyler presented a paper* to the Society in 1906 setting forth in a most admirable way the peculiarities of the method and its application to actual dams.

The method is certain to have an important place in future dam construction. It has two fundamental advantages: First, in sorting out the fine particles and placing them in the center of the dam, thus insuring complete water-tightness; and second, in the use of power in place of muscle to the greatest extent, so that the labor cost and the animal cost of construction are reduced to a minimum.

It is sometimes possible to place material by the hydraulic process at much smaller cost than by any other method.

On the other hand, several hydraulic dams have not proved to be stable. Failures, usually during construction, have caused great losses, and their occurrence has been discouraging.

There may have been more than one cause of failure, but one cause has certainly predominated. In the interior of the dams there have been masses of clay and other fine-grained material, that have not consolidated to the point of stability. Instead of forming an integral part of a solid dam, these have remained in almost liquid form, dividing the dams and tending to disrupt them. In this respect, hydraulic-fill dams are on a different basis from other earth dams.

If the hydraulic method of dam construction is to be successfully used, this element of weakness must be eliminated.

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* *Transactions,* Am. Soc. C. E., Vol. LVIII, p. 196.

There seem to be two promising ways of eliminating it. The first and most natural one is to increase the size of the dam until the solid parts forming the toes are amply strong to resist the full fluid pressure of the unstable core. The second consists in selecting material and handling it in a way to secure drainage and consolidation of the core, so that the whole dam will act as one solid mass.

If core material can be fully drained and consolidated, there is no reason why a dam built by the hydraulic method on a section that is suitable for an earth dam built dry should not be safe. If drainage and consolidation of the core is not secured, however, safety can only be reached by making each toe large enough to stand the full pressure of the liquid core, and in that case, in order to be safe, a dam built by the hydraulic method must have flatter slopes and a larger section than is otherwise needed for an earth dam.

It is interesting to note that Clemens Herschel, Past-President, Am. Soc. C. E., in discussing Mr. Schuyler's paper in 1906, made the point that a larger section would be required for stability; Mr. Schuyler took exception to this, and stated that in his experience there was no reason for building a dam of greater dimensions because the material was placed in it by the hydraulic method.

The advantages and economies of the hydraulic method are such that it will often be good business to use it, even though the required volume of the dam should be greater. If work can be built at half the cost per cubic yard, twice as many cubic yards can be placed for the same money.

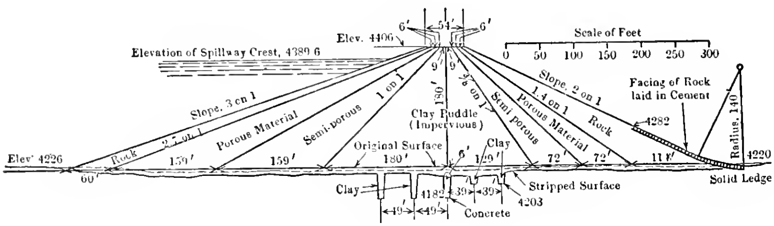
The number of failures with hydraulic-fill dams growing out of this fundamental condition of fluid cores and inadequate toes has been such as to make it clear that this condition of instability has not been recognized in the designs. Mr. Schuyler's excellent paper contains no discussion of this point. Looking at it from the standpoint of thirteen years afterward, it is easy to see how this condition could have been overlooked and to see, also, how some of the early failures were attributed to other causes.

Now, however, enough experience has been gained so that a better analysis may be made. To insure success with future hydraulic dams, this analysis must be thorough. It is the writer's thought that it will be possible to make it in a way to secure as high a degree of safety in hydraulic-fill dams as is required, and is customary, in other engineer-

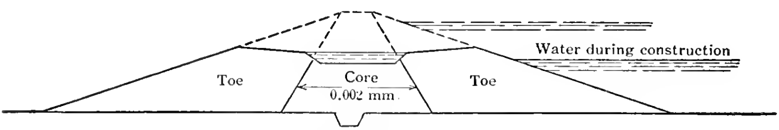
ing structures. It may be that we do not yet have all the necessary data; but, if not, the best way to find what is lacking is by using what we have.

Character of Core Material.

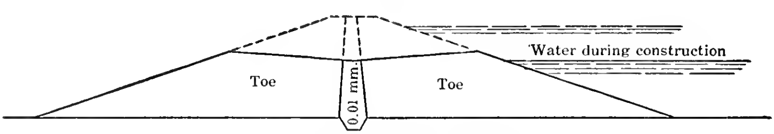
The first point to be considered is that, in many or perhaps most hydraulic-fill dams, the core material is so fine in grain size that it is incapable of drainage. By that is meant that it is incapable of drainage within a reasonable length of time. The lower parts of the core do not become stable before the upper parts are placed upon them.



CROSS-SECTION OF DAM NO. 2 AT NECAXA, MEXICO.
SHOWING
DIMENSIONS, CUT-OFF TRENCHES AND THEORETICAL DISTRIBUTION OF MATERIALS.
FIG. 1



TYPICAL SECTION OF HYDRAULIC FILL
DAM DURING CONSTRUCTION.
FIG. 2



ILLUSTRATING PROPOSED SECTION WITH
NARROW COARSE-GRAINED CORE.
FIG. 3

In general, all the material placed in hydraulic-fill dams may be divided into two classes, namely, toe material and core material. Mr. Schuyler presented a picture of materials divided into several classes, the coarsest being found at the outside and the finest in the middle (Fig. 1*). Practical experience does not show that the material is graded in quite that way. There is some grading in the toes and the average size of particles near points of delivery of material near the outer slopes is

* Fig. 1 is reproduced from *Transactions*, Am. Soc. C. E., Vol. LVIII, p. 243.

greater than away from those points and near the core; but, practically speaking, this gradation is not very important. Ordinarily, all the toe material is of coarse particles when first placed. Afterward, passage of silt-laden water from the operation of hydraulicking partly fills the voids with fine material, but the process stops itself before they are all filled. The toes readily drain and all the stability naturally inherent in the stock is obtained.

The core may be defined as that part of the dam deposited from water in the central pool. In the writer's experience, core material is homogeneous. At any level there is no appreciable difference in grain size between the middle of the core and its farthest extremities.

The principles determining the size of particles deposited in the core, or not deposited, are the same as the ones that apply in a sedimentation basin of a water-works plant. The larger the area of the pool in proportion to the quantity of water that goes through it, the more complete will be the subsidence, and the smaller will be the limit of size of particles retained.*

Most hydraulic-fill dams have been built with good-sized pools in the center during construction (Fig. 2), in which sedimentation has been fairly complete. The writer has examined samples of the core materials from a number of dams. The samples are rather surprisingly alike in grain size. They ordinarily contain particles in large quantities down to a limit between 0.001 and 0.002 mm. (or sometimes 0.003 mm.) in diameter. Generally speaking, all smaller particles have been carried away by the escaping water and have not remained in the core.

It should be said that the determination of the exact size of these small particles is by no means as precise as the determination of the size of grains of filter sand. The results are reached by the microscope with a micrometer and are to be considered as roughly approximate only. It has been the intention to use a basis as nearly as possible comparable to that adopted for the larger particles in sand analysis, which is to use as the diameter of any particle the diameter of a sphere of equal volume. Following this rule the width, rather than the length, of small particles is measured.

Core material then, as a matter of observation, consists of particles from this size up to the size of the smallest particles retained in the

* "On Sedimentation," by Allen Hazen, M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. LIII (1904), p. 45.

toes. In a general way, this size may be taken as 0.03 mm., or ten to fifteen times as great as the limit of size of particles that are retained in the core.

Speaking of core materials in the terms that are used in describing sand, it may be said that the effective size of core material is ordinarily about 0.002 mm. This size is so small that one who is not accustomed to microscopic work has little conception of it. For comparison, it may be stated that ordinary filter sand has an effective size of from 0.3 to 0.4 mm., while dune sand, being the finest material usually spoken of as sand, has effective sizes ranging from 0.15 to 0.20 mm.

Without attempting precision, and using round figures, the core material is one-hundredth of the size of dune sand. This means (assuming that the laws of flow and the laws of capillarity applying to the finest sands apply also to these still finer materials) that, other things being equal, the drainage of core material will take ten thousand times as long as corresponding drainage of fine sand. Fine dune sand would drain as much in an hour as core material in a year. It means, further, that the height to which water can be held by capillarity is ten thousand times as great as the height at which it is held by fine sand. If fine sand will hold water by capillarity to a height of an inch, as it will, then core material like that shown by the samples will hold water by capillarity to much more than the full height of any dam.

The reason why this core material does not drain is therefore clear. It seals itself up and becomes practically water-tight.

With the dimensions existing in dams that have been built, assuming that the laws of flow known to apply to the finest sands apply also to the still finer materials, it will take years for the excess of moisture to drain out, as it must do before the solidification of the material is possible.

As a practical proposition, drainage is not possible with such fine materials. By that is meant such prompt and complete drainage as will result in solidification during the construction of the dam.

Construction records and samples show approximately what happens. Core material of the fineness already described goes down first in the form of soft mud in which the voids filled with water are at least 70% of the total volume. Such mud is very soft.

The percentage of voids furnishes, on the whole, the best index of consolidation and stability. In itself, it is not an adequate basis of

comparison, because different kinds of core material may have different degrees of stiffness with the same percentage of voids; but, notwithstanding this difference, the percentage of voids is the best index of consolidation so far available.

The material when it goes down contains 70% of voids. Under these conditions, the minute solid particles are held apart by the water contained between them, and the passages through which water can pass are much larger than they would be with a more compact arrangement of the same material. Water drains from this material gradually, and the material consolidates.

The drainage may be horizontal, in which case the surplus water finds its way through the core material to the toes and escapes. There is, however, a shorter way out, and it appears probable that most of the drainage takes place vertically. That is to say, the solid particles settle down and consolidate while the water moves upward between them to the top. This consolidation takes place gradually at rates depending on the dimensions of the dam and also on variations in the effective size of the core material; for while the writer considers all this material broadly as having an effective size of 0.002 mm., there are no doubt considerable variations in size and permeability.

Experience shows that consolidation goes on so that after a period of from a few months to two or three years in the ordinary course of dam construction, it will have been consolidated to a point where the voids are about 50 per cent. As the consolidation increases, the sizes of the passages between the grains become smaller, and the flow becomes less rapid and the process of consolidation goes forward more and more slowly.

Material with 50% of voids when taken out of a boring is described as material having the consistency of stiff putty. It is capable of standing up in a boring driven beyond the casing for several feet, and it offers great resistance to penetration.

One of the best field methods of testing the consolidation of core material has been to find the depth to which a 1½-in. pipe could be forced into it by two men. This method of testing has been used in several dams. It has been possible to co-ordinate the penetration so found with records of the percentage of voids. In a general way, penetration by 1½-in. pipe pushed down by two strong men extends to the point where the voids are about 50 per cent. In other words, the 50%

material is so stiff that it can no longer be penetrated to any considerable depth by this method.

Tests of material by letting down cannon balls, etc., are less searching. The penetration does not go as far.

Material with 50% of voids in a considerable depth acts essentially as a liquid. It exerts the full lateral pressure corresponding to its height and weight per cubic foot, and when the resistance of the toe is overcome, this material moves forward and flows. Precise limits cannot be set, but this is the general result of observation at Calaveras as a result of determinations of voids in many samples of material that did flow and in other samples of material that did not flow. This refers to the Calaveras Dam* near San Francisco, Cal., which slipped as it was approaching completion on March 24th, 1918, investigation of which afterward gave an unusual opportunity for studying some of the conditions that grew out of the methods of placing material that had been used. (See Figs. 4 to 6.)

Core material becomes solid when it is dried. Core material dried in the summer sun at Calaveras was consolidated until only 35% of voids remained. In this condition, it was only a little less strong and stable than the natural sandstone in the neighboring hills.

Core material consolidated to 35% of voids would form the strongest and most stable kind of an earth dam. No large toes would be required to contain it, for on any reasonable slope it would be stable by itself. Such consolidation, however, as far as is known, is reached only by complete drying. Unfortunately, drying cannot be applied to the core of a large dam.

Without attempting precision of statement, it is the writer's judgment that if core material like that at Calaveras could be consolidated to 40% of voids, it would be sufficiently stable to do its share toward resisting the pressures that come upon the dam without tending to disruption. Perhaps this degree of stability would be reached before consolidation had proceeded as far as 40% of voids. There is a middle ground of uncertainty. Material with 50% of voids is still unstable; and between this limit and 40%, one cannot be certain just where to draw the line.

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* See *Engineering News-Record*, April 4th, 1918, p. 679, and December 26th, 1918, p. 1158.

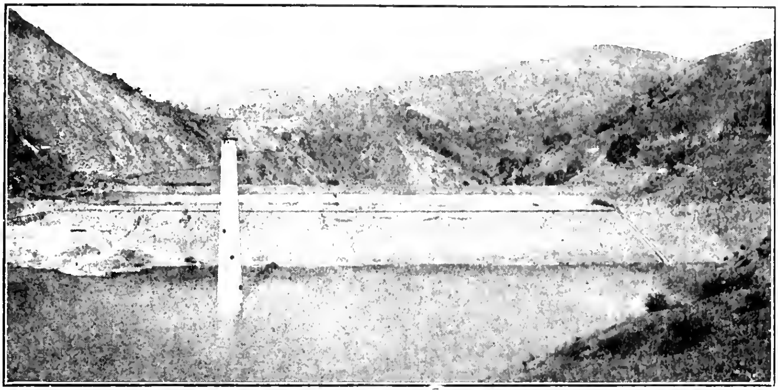

FIG. 4.—CALAVERAS DAM DURING CONSTRUCTION, SHOWING UPPER AND LOWER TOES, WITH POOL BETWEEN. WATER IN FOREGROUND IS IN RESERVOIR ABOVE DAM.

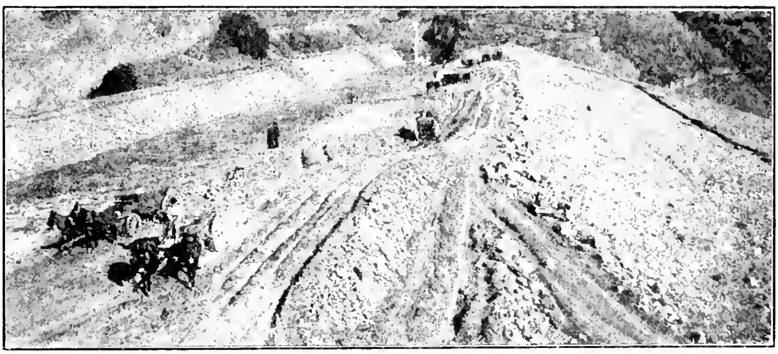

FIG. 5.—CALAVERAS DAM DURING CONSTRUCTION, SHOWING TOES AND CENTRAL POOL A FEW DAYS BEFORE THE SLIP.

FIG. 6.—CALAVERAS DAM AFTER THE SLIP. ON MARCH 24TH, 1918, 800 000 CU. YD. OF MATERIAL MOVED 300 FT. UP STREAM AND DROPPED 100 FT. IN ELEVATION, TURNING ALSO 30° TO THE RIGHT.

It is interesting to note that the 1½-in. pipe used in the penetration tests only reaches to points where the material is still unstable. It follows that tests of this kind do not and cannot demonstrate stable material. Tests made by cannon balls or other less searching means are equally defective. It cannot be considered, in the light of the Calaveras experience, that tests made by such methods throw much light on conditions of stability. They may at times serve a purpose in showing lack of stability, but that is as far as use can be made of them.

It is the writer's thought that the best method of investigating consolidation and stability is by making borings. There are difficulties, for boring usually involves stopping the sluicing of material while the holes are being put down; but it does lead to more definite results. Borings can be driven and samples taken from the bottom of the borings for physical inspection and for determination of the percentage of voids.

The Determination of the Percentage of Voids.

This is a very simple matter, but experience shows that it is easy to go wrong, and for that reason a brief statement of methods that have been found suitable will be given.

The samples taken from the bottom of test borings are saturated with water. A determination of water content, therefore, can be made a measure of voids. This procedure is sound so far and only so far as the voids are completely filled with water. A useful check can be obtained from the specific gravity of the moist material.

The specific gravity of the solid particles of core material may be taken as 2.65. It may be that in some locations other specific gravities will be found, but in the writer's experience, actual values differ little from this mean value.

In determining the specific gravity of these exceedingly small particles, the most careful manipulation is required to get all the air out of the dry material. Methods similar to those used for determining the specific gravity of Portland cement are appropriate, but water can be used.

A table can be made showing the weight of the solid particles, the weight of water, the percentage of water by weight, and the specific gravity of core material containing various percentages of voids.

Table 1, in convenient and somewhat condensed form, gives these values for saturated clay.

TABLE 1.—SATURATED CLAY.*

Specific Gravity of Solid Particles, 2.65.

Percentage of voids.	Percentage of water, by weight.	Specific gravity. Wet.	WEIGHT PER CUBIC FOOT.	
			Wet.	Dry.
40	20.1	1.990	124.2	99.2
41	20.8	1.974	123.1	97.5
42	21.5	1.957	122.1	95.9
43	22.2	1.940	121.1	94.2
44	22.9	1.924	120.0	92.6
45	23.6	1.908	119.0	91.0
46	24.3	1.891	118.0	89.3
47	25.0	1.874	117.0	87.6
48	25.8	1.858	116.0	86.0
49	26.6	1.841	115.0	84.3
50	27.4	1.825	114.0	82.7
51	28.2	1.808	112.9	81.0
52	29.0	1.791	111.9	79.3
53	29.8	1.775	110.8	77.7
54	30.6	1.759	109.8	76.0
55	31.5	1.743	108.7	74.4
56	32.4	1.726	107.6	72.8
57	33.3	1.709	106.6	71.1
58	34.2	1.692	105.6	69.5
59	35.1	1.676	104.5	67.8
60	36.1	1.660	103.5	66.1
61	37.1	1.643	102.5	64.5
62	38.1	1.626	101.5	62.8
63	39.1	1.609	100.5	61.2
64	40.1	1.593	99.5	59.5
65	41.2	1.577	98.5	57.8
66	42.3	1.560	97.4	56.2
67	43.4	1.543	96.4	53.5
68	44.5	1.527	95.4	52.9
69	45.6	1.511	94.4	51.2
70	46.8	1.495	93.4	49.6

* This table is not to be used for any material that has lost water by evaporation so that the voids are not completely filled with water.

When a sample is taken from a test boring, a portion is put in a dish and weighed. The weighed material is dried at or above the boiling point to constant weight, and the percentage of moisture computed. As even a little drying before the first weight affects the result, the samples should be weighed on the spot when first brought to the surface; to do this, portable equipment must be used. After the first weighing, samples may be taken to the office or laboratory for the completion of the process. When the percentage of moisture

by weight is found, the corresponding percentage of voids is obtained from Table 1.

As a check, the specific gravity of another part of the sample is determined. This is obtained by putting a weighed portion of the moist mass into a graduated cylinder partly filled with water and noting the increase in water level. The specific gravity is the ratio between the weight of material added and the weight of the water that corresponds to the increase in level, and so to the volume of material placed in the cylinder. With this specific gravity determined, Table 1 indicates the percentage of voids.

The percentage of voids determined by the two methods with good manipulation should check within 1 or 2 per cent. If it does not, there is something wrong and the error must be found and eliminated.

To determine the weight of the coarse and hard toe material, no better method has been found than to make an excavation accurately to a dimension of 1 cu. yd., or other convenient size, and to weigh the excavated material on platform scales. Percentages of moisture vary, and the weight of dry material affords the best basis of comparison. An average sample of material on the scales is taken for determining the percentage of moisture, and the results are reduced to weight of dry material per cubic foot.

Draining Fine Material.

The writer is fully satisfied that there is no practical way of rapidly draining core material as fine in grain size as that described previously. He has considered it from a theoretical standpoint and also from the standpoint of practical experience.

After the material reaches a condition of 50% of voids, 6 cu. yd. must be compressed into 5 cu. yd. of 40% material by the exclusion of 1 cu. yd. of water before full stability can be counted on. This water, amounting to one-sixth of the whole volume of core material, must be expelled. The computed rate of flow through material with an effective size of 0.002 mm. is very slow. The rate depends on, and is proportional to, the hydraulic slope. With a slope of 10% (which is as steep as is usually found) the computed rate of flow as a solid column of the full area of the section is 0.32 mm. daily. At this rate, 80 days are required for the water to move 1 in. and 2.6 years for it to move 1 ft. This calculation cannot be used with assurance as estab-

lishing the exact rate of flow, but it is the writer's judgment that the actual rate is as likely to be below as above the result given. It is clear that, for a large dam, complete drainage and consolidation may be a matter of many years.

From a practical standpoint, it may be recorded that a 6-in. well driven 60 ft. in saturated core material having voids averaging 50%, with the casing perforated freely to admit water, stood empty for weeks. Not enough water drained from this material to raise the water in the well. This may represent the effect of capillarity. With such a degree of tightness, it is clearly useless to attempt to secure consolidation by any method depending on additional drainage outlets.

Measuring Core Pressures.

An interesting method of measuring the pressures actually existing in core materials has been suggested by A. T. Goldbeck, Assoc. M. Am. Soc. C. E.* By this method, small test cells are built into the core material. Some are placed with horizontal and some with vertical faces, arranged to indicate pressures on the faces during construction and afterward. Such devices are reported to have been placed in hydraulic-fill dams now building by the Miami Conservancy District. The results of observation through a certain period have already been recorded These observations indicate, as would be expected, that the horizontal and vertical pressures are the same at first and until the material has become somewhat consolidated. Afterward, horizontal pressure increases less rapidly than vertical pressure, and the inference may be drawn that this represents solidification of the material in which the cells are placed to a point where the full horizontal pressure is no longer produced.

This is certainly an interesting method of test and one that may throw light on the conditions of core material.

It reminds the writer of one of his early experiences, which related to different circumstances, but possibly the same underlying principles are involved. It was proposed to build large and heavy structures in which the weight would be well distributed on a foundation of stiff silt. The question was presented as to whether the foundation was sufficient to carry the weight. An apparatus was provided by which test areas of 1 sq. ft. at the level of the proposed foundation were

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* *Engineering News-Record*, April 18th, 1918, p. 758.

loaded. The results of the tests were most satisfactory. The material carried more than the expected loads, with only insignificant settlements. When the actual structure was built, however, there was considerable settlement. The actual settlement was many times greater than had been indicated by the tests.

The explanation is simple enough. The single square foot that was loaded distributed the weight applied to it to a much larger area a short distance below. What was loaded was in effect a pyramid with a flat top of 1 sq. ft. The full applied weight per square foot was carried only at the top, and the unit stress rapidly became less going downward as the area of the pyramid increased. A thin layer of material just below the footing actually got the pressure and was compressed accordingly, and in this way the slight observed settlement was produced. Lower down, however, the unit pressure was lower and there was no appreciable compression.

When the structure was built there was no chance for a corresponding distribution of pressure. The whole area underneath was loaded, and the weight had to be carried through the full depth of silt and the silt was compressed. A corresponding settlement would no doubt have taken place in the test apparatus if the material loaded had been a column 1 ft. square all the way down to rock. The writer thinks that because of this dispersion of load it is generally true that a small test area will carry more per unit than a larger one, and it may be that the same conditions will be found to apply to the test cells built into the core of a dam.

In view of all the information now available, the only safe course to follow, so long as the core material is like that here described, is to assume that it will produce the full horizontal pressure corresponding to its weight and height; and the toes must be made large enough to resist that pressure with ample safety.

Resisting the Pressure of the Core Material.

The first point to be considered is the coefficient of friction of the material in the toe, sliding either upon the foundation or upon itself. With hard, clean gravel a coefficient of 0.7 or 0.8 might reasonably be expected, although the data for establishing this coefficient are not as convincing as could be desired. No such coefficient was found, however, in accounting for the Calaveras slip. Instead, it was esti-

mated that the weight of the material pushed forward in the up-stream toe was five times as great as the pressure of core material against it. In estimating that pressure the whole height and weight of core material was included, assuming that it acted as a heavy liquid. This indicated a coefficient of friction of only 0.20. This is to be taken as an average for the whole area on which the slip occurred. It may be recorded, however, that a similar calculation for the lower toe which did not slip indicated a coefficient of 0.22. No one can tell how much more it would have held.

The Calaveras material is softer and perhaps more slippery than the hard particles of glacial drift of the Eastern States; and it would not be reasonable to expect as high a coefficient of friction. It may be, also, that the coefficient of friction under such heavy pressures as are found in the lower part of a high dam will be less than under the small pressures of moderate depths.

Some experiments were authorized by George Wilhelm, M. Am. Soc. C. E., and made by G. W. Hawley, M. Am. Soc. C. E., Resident Engineer at the San Pablo Dam, near Berkeley, Cal. (see Fig. 7), following suggestions of the writer. A 14-in. cast-iron pipe was cut into two short parts, one of which was fixed and the other attached securely to a steel frame which swung freely on an axis about 8 ft. above. Another steel frame securely connected the ends of this axis with the fixed part of the 14-in. pipe and with other parts of the apparatus. Two hydraulic jacks were used and the pressures were computed from the measured pressures on the pistons.

The two pieces of 14-in. pipe were placed in line and the frames held them so that the ends would just clear.

A sample of the material to be tested was placed in the pipe, filling the lower or fixed part and extending some distance into the movable part. Oak planks, cut to fit as a loose piston, were then placed above. One of the hydraulic jacks was placed above it. Pressure was then applied to compress the material in the pipe to any desired extent. Experiments were made with various pressures, the greatest corresponding to a depth of fill of 200 ft. While the material was held under this pressure, the other jack was placed horizontally against the side of the 14-in. pipe with suitable blocking, and pressure applied until there was movement. The ratio of pressures on the two jacks then gave the coefficient of friction.

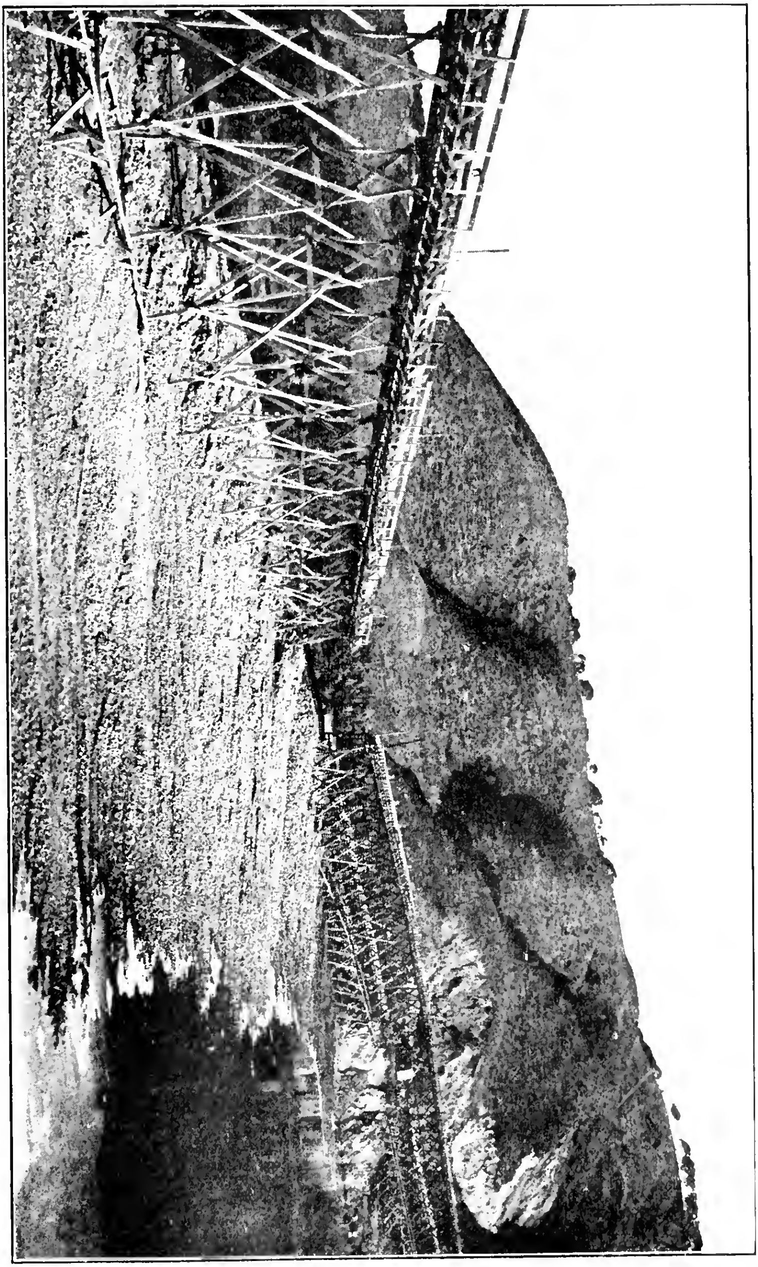

Fig. 7.—San Pablo Dam, Showing Development of Lower Toe, with the Finer Material Passing Over It to the Central Pool.

The steel frame and the pivot at the top was built so that there was no appreciable friction in the apparatus. A slight correction was necessary because the lever arm to the slipping plane was longer than the lever arm to the point on the 14-in. pipe where pressure was applied.

The form of the experimental apparatus was suggested to the writer by a paper by Mr. A. L. Bell on clay pressures.* The apparatus as worked out was more like that used by E. P. Goodrich,† M. Am. Soc. C. E., in his experiments on soil pressures.

The apparatus used differed from both of its predecessors in that tests were made at very much higher pressures. The results may be compared, but it must be remembered that the local material had peculiarities of its own, and that it was no doubt quite different physically from the material tested by Bell and Goodrich.

The writer will not attempt to discuss this matter further, but suggests it as a fruitful topic for further experiment.

Experiments were made by Mr. Hawley with various local materials at various pressures. These showed that, with low pressures, the coefficient of friction was distinctly larger than it was with higher ones. The explanation for this may be that the higher pressures broke down and crushed the particles, and so reduced the relative resistance. After a certain pressure was reached there was less rapid change in the coefficients, and for the higher pressures the coefficients for any material were practically constant.

For material from the local soft sandstone rocks at San Pablo, coefficients of friction of approximately 0.5 were found.

There was one kind of material more slippery than the others for which an average coefficient of 0.45 was found. Other harder materials gave coefficients of 0.55 and more. Sand and gravel from the creek representing the remnants of much harder rocks in the hills (and so corresponding more nearly to the glacial drift of the Eastern States) gave coefficients of about 0.7.

The materials at San Pablo are similar to the materials at Calaveras; and there is reason to think that the coefficients found at San Pablo would apply approximately to the Calaveras materials.

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* *Minutes of Proceedings,* Inst. C. E., Vol. CXCIX (1914–15), p. 233.

† *Transactions* Am. Soc. C. E., Vol. LIII (1904), p. 297.

What then is the explanation of the fact that the Calaveras Dam slip indicated a coefficient of 0.2 while similar materials in the test apparatus show a coefficient of 0.5—two and one-half times as much?

The answer seems to lie in the fact that in the course of construction at Calaveras, before the dam was very high, the construction pool in the center of the dam was sometimes quite wide; so that at some levels the greater part of the width of the dam was composed of fine-grained core material. Afterward the proportion of solid fill was increased and the width of core reduced, but the effects of the wide pool may have been permanently left in layers of core material extending far out under the more solid parts of the toes.

It seems probable that unstable core material placed in this way furnished the lubricant that facilitated and made possible the slip in the dam.

SECTION OF DAM REQUIRED WITH CORE MATERIAL CONSIDERED AS A FLUID.

At Calaveras, the toe material was slightly heavier per cubic foot than the core material. At San Pablo, with fragments of porous sandstone rock predominating in the toes, there was scarcely any difference. With harder material like the glacial drift of the Eastern States, the toe material would be considerably heavier.

For the purpose of a first rough calculation, assume that the weights per cubic foot of toe and core material are equal, as they are at San Pablo. If a coefficient of friction of 0.5 is assumed, each toe must weigh twice as much as the pressure exerted by the core. The pressure exerted by the core is $\frac{1}{2} w h^2$ and the weight of the toe to balance it must be $w h^2$. To produce this weight, a uniform outer slope of 2 to 1 will suffice. In addition, a top width equal to the maximum width of core must be used. If a factor of safety of 2 is required, the outside slope must be made 4 to 1, but in view of the records of slips in actual dams, it may well take a higher factor of safety. A slope of 5 to 1 will give a factor of safety of 2.5 and a slope of 6 to 1 will give a factor of 3. Where toe material is considerably heavier than the core, as would be the case with harder and heavier rocks, the slopes could be reduced in proportion to the increased specific gravity without reducing the factor of safety. Thus, with toe material 20% heavier than core material, a slope of 1 to 5 would allow a factor of safety of 3. Very few hydraulic dams have been built with sections as large as this

line of thought suggests. The Gatun Dam at Panama heads the list, and is even larger.

A great many cubic yards are involved in such a large section, but if the work is done cheaply enough per cubic yard, it may be economical to use the extra volume. Safety can be secured in this way; and it may be that this procedure is the best one to follow.

Dimensions of a Number of Dams.

To see what these slopes would call for in the way of section in comparison with earth dams that have been actually built either by the hydraulic method or as dry fill, the following comparison is made. Assuming a freeboard of one-tenth the greatest depth of water, H, and a top width of 0.25 H and uniform slopes, the cross-sections of dams in terms of the greatest depth of water would be as follows:

Slope.	Volume.
3 to 1	3.9 H^2
4 to 1	5.1 H^2
5 to 1	6.3 H^2
6 to 1	7.5 H^2

The actual dimensions of a number of dams are given in Table 2.

Rock-fill dams are not included, but rock fill forms some part of a number of dams in the list. No dams holding less than 64 ft. of water are included.

The Necaxa Dam slipped, but was afterward rebuilt on the original section. The Big Meadows Dam is being raised with an enlarged section.

Increasing the Grain Size of Core Material.

The second way of increasing stability is to use core material that will consolidate more rapidly and thoroughly. There is only one way to insure this; that is to increase the grain size of the material allowed to remain in the core. With pools and water quantities actually used in the dams known to the writer, particles smaller than 0.001 mm. and perhaps up to 0.002 mm. have been wasted. Everything larger has gone into the dam.

In some cases, an effort has been made to secure completeness of deposition of these fine particles to avoid waste and to increase the yardage accounted for in the dam.

TABLE 2.—DIMENSIONS OF A NUMBER OF EARTH DAMS THAT HAVE STOOD SUCCESSFULLY.

Dam.	Height to flow line, H.	Area of section, in square feet, A.	Ratio, $\frac{A}{H^2}$	Freeboard.	Width, in Feet. Top.	At flow line.	50 ft. below flow line.	100 ft. below flow line.	Bottom, W.	Ratio, $\frac{W}{H}$
*Gatun	78	99 200	16.30	30	100	397	1 469	....	1 990	25.5
*Big Meadows	64	24 300	5.93	20	30	160	460	....	548	8.56
*Coquitlam	83	38 700	5.61	15	40	145	521	....	702	8.48
*Cambria	82	31 200	4.65	13	20	98	429	....	685	8.34
Ashokan	90	35 400	4.37	20	34	112	400	....	650	7.23
Druid Lake	82	27 900	4.15	5	60	90	390	....	582	7.10
San Andreas	80	26 200	4.10	5	30	58	387	....	606	7.58
*Paddy Creek	120	58 200	4.05	25	23	161	414	664	757	6.30
*Somerset	92	33 200	3.94	13	25	78	375	....	616	6.67
San Leandro	65	16 350	3.88	5	30	56	335	....	457	7.04
*Haiwee	75	21 600	3.85	14	20	90	340	....	465	6.20
Croton	96	33 400	3.62	24	30	126	336	....	528	5.50
Tabeaud	86	26 400	3.57	8	20	60	345	....	553	6.44
*Necaxa	164	90 800	3.36	16	54	136	386	636	954	5.81
Cold Spring	88.5	26 200	3.34	10	20	70	320	....	512	5.79
Belle Fourche	100	33 100	3.31	15	20	65	284	656	656	6.56
Lahontan	112	40 900	3.25	12	20	80	330	580	640	5.72
Santa Maria	85	23 500	3.25	8	20	60	310	....	485	5.71
Pilarcitos	74	17 600	3.22	5	30	56	288	....	415	5 61
Morris	90	25 700	3.18	9	20	60	309	....	502	5.58
Borden Brook	64	12 700	3.10	7	24	49	280	....	337	5.27
Honey Lake	90	25 000	3.08	6	20	50	300	....	500	5.56
Goose Creek	137.5	54 900	2.90	7	16	54	304	554	741	5.39

* Hydraulic fill, wholly or in large part.

To increase the effective size of core material, it is necessary to increase the limit of size of particles to be wasted. This can be done by narrowing the pool or by increasing the quantity of water passing it (see Figs. 3, 8, 9, and 10). On one occasion at San Pablo, to test this out, the toes were allowed to increase in height for a time without raising the pool. This was continued until the pool almost disappeared. Hardly more than a muddy creek remained in the middle of the dam. The core became comparatively narrow and much coarser in grain size. The effective size was increased to approximately 0.01 mm. Finer particles were all wasted. In other words, the core material was, say, five times as great in grain size. It had, therefore, twenty-five times as great draining capacity, and only one twenty-fifth of the capacity to hold water by capillarity.

Material placed in this way had a much better chance of drainage; first, because the core was narrower and there was less water to be

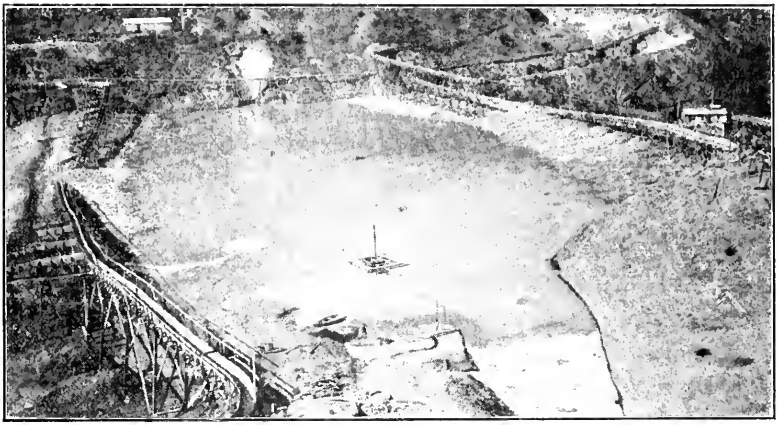

Fig. 8.—San Pablo Dam, Showing Maximum Width of Central Pool.

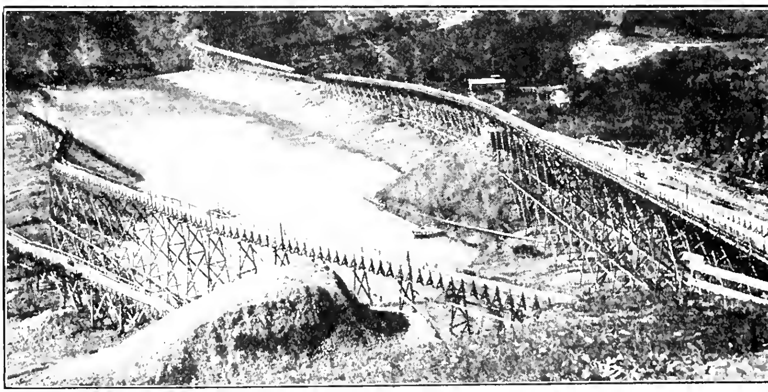

Fig. 9.—San Pablo Dam, Showing Ordinary Width of Central Pool Producing Core Material 0.002 Mm. in Size.

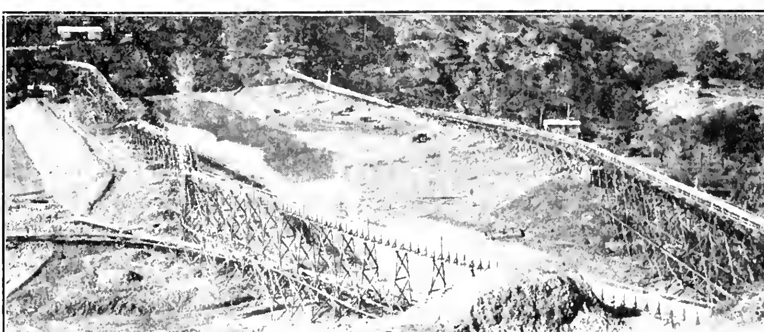

Fig. 10.—San Pablo Dam, Showing Central Pool Greatly Reduced in Width for Purpose of Increasing Grain Size of Core Material. It was Pushed to a Narrower Width than Shown.

removed; second, because the water had a shorter distance to go; and third, because, other things being equal, the water would get away twenty-five times as fast. After a few weeks of operation in this manner, the work was stopped temporarily, which gave an opportunity to examine the deposited core material. After only a few days it became hard enough to walk on, many times more solid than ordinary core material.

In one other respect this coarse-grained puddle differed from ordinary puddle. There was a small relative range in its grain sizes. The fine particles were eliminated, and the volume of puddle produced was reduced, but there was no very great change in the quantity and character of the coarser particles. These coarser particles constituted the whole mass of the coarse-grained puddle. With ordinary puddle, they were mixed with a large additional volume of fine-grained stock. The grains in the coarse-grained puddle were thus more nearly of the same size, and it followed that, other things being equal, the percentage of voids was greater. This was found to be the case in the test at San Pablo, and after the material had become hard and stable, it had a percentage of voids that would have indicated lack of stability in ordinary stock. This is an illustration of the fact that voids used as an index of stability can only be properly compared for the same kind of stock.

If this method of increasing the grain size of core material were to be followed throughout the construction of a dam, obviously there would be two results. First, a great deal of fine material would be wasted. The quantity would depend upon the quantity of such material in the stock used. In the natural course of events most of this would be deposited harmlessly upon the bottom of the reservoir. Second, a dam built in this way would be much more stable but theoretically not quite water-tight. There would be an appreciable amount of seepage through core material of this grain size.

The amount of seepage loss may be estimated approximately. Assuming that the laws of flow are the same as they are in the finest sand to which experiments have extended, it was estimated that at the San Pablo Dam if the whole core material could be made 0.01 mm. and if the rest of the dam had contributed nothing to tightness, the theoretical rate of seepage would be 280 000 gal. per day. The loss of this quantity of water would not be a serious drain upon the supply,

if it adds to stability. Practically, as is known from filter experience, considering the core material as a filter, it would soon silt up and become water-tight.

As a practical proposition in dam construction, core material having a grain size of 0.01 mm. is to be accepted as sufficiently fine from the standpoint of water-tightness. This size of 0.01 mm. is not given as a precise limit. It may be that still coarser material would give sufficient tightness or that finer material would drain sufficiently. The size is mentioned because it is the size of material that was actually found possible to produce at the San Pablo Dam by reducing the size of the pool to a minimum, and because other considerations suggest that it may be suitable.

The question remains as to whether a dam in which the pool and water quantities were so adjusted as to hold the effective size of core material at 0.01 mm., or at some other selected limit, and in which the core material was never permitted to become very wide, would consolidate itself as the dam increased in height to an extent that would eliminate lateral pressure of core material.

It is the writer's idea, that a dam built in this way would certainly be more stable and safer than one in which the core material contained an additional quantity of finer particles.

This thought is similar to an idea expressed by D. C. Henny, M. Am. Soc. C. E., who stated:*

"Probably the nearest approach to a perfect core of great thickness which can be hydraulicked, is one composed of fine sandy silt, such as is generally found in the arid West, having little cohesiveness, good self-drainage qualities, becoming hard and solid after a short time, and yet being, if not perfectly, at least practically water-tight."

Mr. Henny's description may be taken as an accurate description of the writer's idea of 0.01-mm. material. It certainly does not apply to 0.002-mm. material. Mr. Henny's other propositions in regard to fine core material such as is ordinarily used, are believed to be well founded.

The Use of Rock Fill.

In building hydraulic-fill dams, the débris above the solid rock has been most easily worked and extensively used. Such débris is frequently fine in grain size, and its use may result in an excess of core

* *Transactions*, Am. Soc. C. E., Vol. LXXIV (1911), p. 82.

material and a deficiency of toe material. To correct this tendency, rock fill has been added to the toes of a number of dams.

The rock fill has usually been placed as dry fill; that is to say, by blasting, steam shovel, and cars or carts. The cars or carts run on the toes of the dam and deposit material at the same time that the hydraulic process is being used to fill the interior.

At the San Pablo Dam (see Figs. 11 and 12), a similar result has been reached by handling the rock after blasting by the hydraulic method. Open flumes were used with a flow of from 15 to 20 cu. ft. per sec. A 6% slope was necessary as long as wooden flume bottoms were used. With steel flumes, equally favorable results were obtained with a 4% slope. About 3 000 cu. yd. per day were placed, on an average. Pieces of broken rock up to 1 cu. ft. in size were handled under these conditions. By blasting the hardest rock available, it was possible to get material for fill that contained relatively few fine particles, and all of the small quantity of very fine material was wasted. Large additions to the toes of the dam were made in this way.

Working a quarry with a high face, it was possible to throw down great quantities of material in one large blast, and to wash many thousands of yards into the dam from a single position of monitors and flumes. The economy resulting from operating so long in one place, as compared with moving the equipment all over the hillside to pick up scattered and relatively thin deposits of débris above the rock, turned out to be fully equal to the additional cost of rock excavation; and rock fills, built in this way, cost no more per cubic yard than fill made from débris.

On the other hand, the fill made in this way is believed to be heavier, and to have a higher coefficient of friction which gives it additional value as toe material. The practical methods of handling rock fill were worked out by Mr. Hawley and D. W. Albert, Assoc. M. Am. Soc. C. E.

Quicksand Conditions in Dams.

When a granular material has its pores completely filled with water and is under pressure, two conditions may be recognized. In the first or normal case, the whole of the pressure is communicated through the material from particle to particle by the bearings of the edges and points of the particles on each other. The water in the pores is under no pressure that interferes with this bearing. Under such conditions,

the frictional resistance of the material against sliding on itself may be assumed to be the same, or nearly the same, as it would be if the pores were not filled with water. In the second case, the water in the pores of the material is under pressure. The pressure of the water on the particles tends to hold them apart; and part of the pressure is transmitted through the water. To whatever extent this happens, the pressure transmitted by the edges and points of the particles is reduced. As water pressure is increased, the pressure on the edges is reduced and the friction resistance of the material becomes less. If the pressure of the water in the pores is great enough to carry all the load, it will have the effect of holding the particles apart and of producing a condition that is practically equivalent to that of quicksand.

An extra pressure in the water in the pores of such a material may be produced by a sudden blow or shock which tends to compress the solid material by crushing the edges and points where they bear, or by causing a re-arrangement of particles with smaller voids. An illustration of this can be seen in the sand on the seashore. Such sand, comparable to dune sand in size, is usually found to be saturated with water for a certain distance above the water level. This condition is maintained by capillarity. If a weight is slowly placed on this saturated sand, there is a slight settlement, the grains of sand coming to firmer bearings and the weight is carried. A sharp blow, as with the foot, however, liquefies a certain volume and makes quicksand. The condition of quicksand lasts for only a few seconds until the surplus water can find its way out. When this happens the grains again come to solid bearings and stability is restored. During a few seconds after the sand is struck, however, it is almost liquid, and is capable of moving or flowing or of transmitting pressure in the same measure as a liquid.

Fine-grained sand in which this condition exists is called quicksand. The properties of quicksand are well known. Fine-grained sand saturated with water and then mixed with an additional 5% of water acts practically as a liquid. It will flow through small orifices or in a pipe at a 5% slope. The sand in a mechanical filter in process of washing is a typical case. When the sand is drained, in the filter, it forms a bed as hard as any sand bed. When subjected to a reverse current of water strong enough to slightly lift it, however, the volume is increased by perhaps 5%, and it becomes liquid. An object can

FIG. 11—EXCAVATING ROCK AT SAN PABLO DAM BY HYDRAULIC JET, AFTER BLASTING.

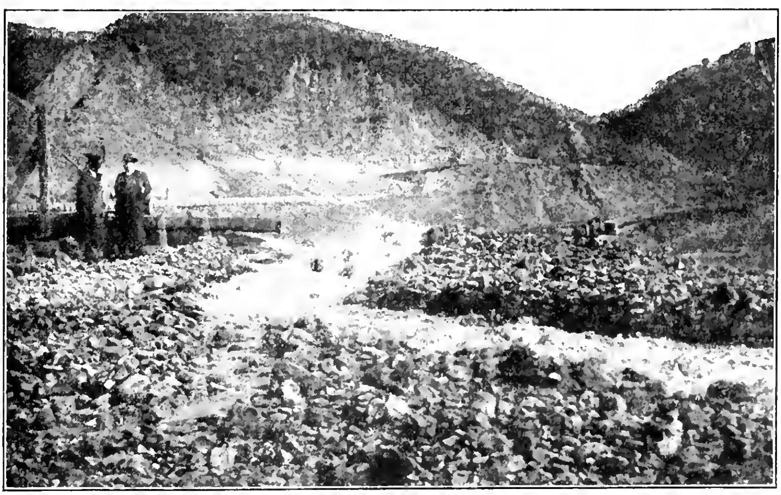

FIG. 12.—PLACING ROCK HYDRAULICALLY IN SAN PABLO DAM, FRAGMENTS UP TO 1 CU. FT. BEING HANDLED BY THIS METHOD.

then be pushed through it with scarcely more resistance than would be offered by a liquid of high specific gravity.

The conditions that control the stability or lack of stability in quicksand may also control the stability or lack of stability of materials in dams.

The puddle clay core of an hydraulic-fill dam is physically like quicksand, but with particles one hundred times smaller in diameter and a million times smaller in weight. It has the instability of quicksand in full measure and it retains it for a long time, or perhaps indefinitely.

With the coarse-grained part of an hydraulic-fill dam, that is to say, with rock toes, there may be also, at times, a similar condition. Generally speaking, it would be expected that such coarse-grained materials would have sufficient drainage to let out surplus water and prevent the possibility of an excess sufficient to destroy its stability. With hard-grained materials from glacial drift of New England and the Northern States, it is hard to conceive of a lack of drainage in gravel that would permit the accumulation of an excess of water. With the softer materials of the Pacific Coast, however, the conditions may be different. In the first place, these soft rocks by partial crushing under pressure produce fine material which tends to fill the remaining spaces and to reduce the drainage capacity.

On the other hand, each increment of loading applied to soft-grained material produces a certain compression and settlement; and with it a reduction in voids. This may happen to a toe of soft rock on the up-stream side of a dam against which water is being stored during construction. There is first an open condition with ample voids and ample drainage. As the dam is built higher, pressure increases; there is compression and reduction in porosity. Each additional increment of loading and compression means that a certain quantity of water representing the difference between the old voids and the new voids must be expelled. As long as the material remains sufficiently pervious to carry off this excluded water, the process of compression is harmless. The surplus water is pushed back into the reservoir and stability is retained. There may come a time, however, when the compression goes forward so rapidly that the surplus water cannot be carried off fast enough. When that point is reached (if it is reached), there will tend to be an excess of water in the interstices

and that excess will transmit some of the pressure that was before carried only by the bearings of solid particles, and the frictional resistance of the material will be less, and perhaps much less, than it was before.

The thought has occurred to the writer, in looking at the material that slid in the Calaveras Dam, that something of this kind may have happened on a large scale—800 000 cu. yd. of fill flowed for a brief space, and then became solid. It was, in fact, so solid that in examining it afterwards, by samples and by borings, it was difficult to see how the material could have flowed—as it certainly did flow.

It may be that after the first movement there was some readjustment of the material in the toe that resulted in producing temporarily this condition of quicksand, and that destroyed for a moment the stability of the material and facilitated the movement that took place.

This will not account for the initial movement; but the initial movement of some part of the material might result in accumulating pressure, first on one point, and then on another, successively, as the early points of concentration were liquefied and in that way a condition comparable to quicksand in a large mass of material may have been produced.

Summary.

To summarize briefly the points that the writer has attempted to make and to apply them practically to dam construction:

1.—It is not well to build an hydraulic-fill dam of material of which any large percentage consists of clay or of particles less than 0.01 mm. in diameter; and in general all such smaller particles may well be wasted and excluded from the dam.

2.—By reducing the construction pool to a minimum, and by controlling it and the quantities of water used for sluicing, the core material may be held to a certain degree of coarseness by wasting all smaller particles. An effective size of 0.01 mm. may reasonably be sought.

3.—To study by borings the actual consolidation of the material, and to adjust the construction of the upper parts of the dam to the demonstrated condition of that which lies below.

4.—To make the toes large enough to resist with an ample factor of safety the whole pressure of the core material as a liquid until there

is demonstration of the solidification of the core to a point where horizontal pressure is eliminated.

5.—To increase the weight and solidity of toes by the use of rock fill, placed hydraulically or otherwise.

6.—Stability is increased by compactness. It is worth while to watch voids closely, and to make every effort to hold them at a minimum. The extra weight is advantageous, but security against compression and re-arrangement with resulting temporary quicksand conditions, can be best reached in this way.

A strict application of these principles may reduce the number of hydraulic-fill dams that are built by eliminating that method of construction from consideration where the available material contains too many very small particles. It may also increase considerably the volume and cost of those that are built. It would seem, however, that following them to a logical conclusion, with such testing as can reasonably be done, will result in eliminating present uncertainties and in putting a most useful method of dam construction on a definite and safe basis.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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NOTES ON THE GUATEMALA EARTHQUAKES, AND EARTHQUAKE-PROOF CONSTRUCTION*

By S. Vilar y Boy,† Assoc. M. Am. Soc. C. E.

Synopsis.

Up to the present time, there has been no possibility of calculating earthquake strains for practical building purposes, due chiefly to the uncertain knowledge of physical conditions of brickwork and masonry in the destroyed or damaged structures. After the use of reinforced concrete had become general in Guatemala, the effect of earthquakes on such structures led to some conclusions as to the destructive power compared with the transverse load for which the damaged or undamaged buildings had been designed, but not much has been done, to the writer's knowledge, in the way of mathematical analysis.

The damage done by the Guatemala earthquake to some steel structures afforded an opportunity to use it as a starting point for more definite study, as shown in this paper.

The abnormal conditions brought about by those earthquakes, together with the World War, compelled the writer to make some tests of various tropical woods which, rough though they are, led him to certain conclusions as to the nature of the strength of wood, which might be extended to other building materials. It also appears from

* This paper will not be presented for discussion at any meeting of the Society, but written communications on the subject are invited for subsequent publication in *Proceedings* and with the paper in *Transactions*.

† Guatemala, Guatemala.

the results of these tests, that some relation exists between the brittleness of wood and its durability.

The reconstruction of Guatemala City after the earthquakes that practically destroyed it in December, 1917, and January, 1918, together with the difficulties of importing building materials on account of the European War, brought up that question mentioned by Rankine as defining the nature of most engineering problems, "What to do rather than what to think, in order to start on the rebuilding work without delay."

It was necessary therefore to investigate practical and reasonable solutions, disregarding elaborate investigations, and from this point of view the writer endeavored to obtain the necessary data to design several buildings of the International Railways of Central America, with which he is connected, as well as others for private parties who called on him for that purpose.

The first point to be determined was of course the force of the earthquake so as to design the structures to stand for an equal shake with the customary factors of safety. This was quite uncertain since all wrecked buildings had been constructed of materials such as raw brick or adobe, brickwork or common masonry, the physical properties of which vary within wide limits; also because buildings of the same type of construction did, or did not, collapse, depending on their location.

As a starting point, the writer had the records published by the Society on the San Francisco earthquake,* stating that none of the concrete buildings designed for a wind pressure of 30 lb. per sq. ft. had collapsed; also a report on the earthquake in Sicily by the Royal Italian Committee estimating the earthquake impact as equivalent to one-twelfth of the weight of the structure for the ground floor, and one-eighth from the second story up. It was necessary, however, to make sure that the Guatemala earthquake had not been stronger than those just mentioned.

The earthquake impact is a force of inertia depending on mass (or weight) and acceleration, the acceleration being, more or less, dependent on the manner in which the structures are supported, as

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* *Transactions*, Am. Soc. C. E., Vol. LIX, p. 208.

in the theory of impact. That is to say, the earthquake is more destructive on bodies likely to vibrate freely than on structures properly braced.

Bearing the above principles in mind, the writer tried to get some instructive data from the ruins of Guatemala City. The only specimens having definite physical properties that could be found were the electric light posts, made of rolled steel I-beams, some of which were bent by the earthquake force. They were, therefore, strained beyond their elastic limit or yield point. Since some did bend and some did not, in the same neighborhood, it follows that they were not strained much beyond the average yield point of steel; otherwise, all should have bent.

Those columns, buried in the ground, were 25 ft. high above the surface and the bend was about 5 ft. above the ground line, as in Fig. 1. The static load, W, equivalent to the earthquake impact, applied at the center of gravity of the bent portion therefore can be obtained as follows, S being the section modulus:

$$W \times 120 = 30\,000\ S.$$

For a $7\frac{1}{2}$-in. I-beam with $3\frac{1}{4}$-in. flange width and $\frac{3}{8}$ in. thick, S was taken as 12. Therefore, $W = 3\,000$ lb.

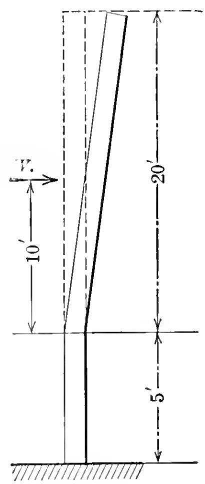

FIG. 1.

This could not be taken as an absolute value for any pole of the same height, but should be considered as a force of inertia for the weight of the bent portion of the beam, or 330 lb. (16.5 lb. per lin. ft. for the 20-ft. length). Hence:

$$\frac{\text{Earthquake Impact}}{\text{Weight of Column}} = \frac{3\,000}{330} = 9.1$$

Or, say, 9, in round numbers, for a pole buried in the ground, free at the top, and acting as a cantilever.

This reasoning was satisfactorily checked by the formula for the acceleration of an earthquake given in the Encyclopedia Britannica, the writer thinks on Milne's authority, as follows:

$$a = \frac{1}{6}\,\frac{g\ F\ A\ B}{f\ w}$$

in which

a = acceleration per second per second;

F = ultimate strength, or force per unit surface which when gradually applied produces fracture;

A = area of base fractured;

B = thickness of column;

f = height of center of gravity of column above the fractured base;

w = weight of the portion broken off;

By substituting and calling x the breadth of a rectangular beam, $A = x\,B$, and

$$\frac{A\,B}{6} = \frac{x\,B^2}{6} = S$$

where S is the section modulus for a rectangular beam. Then

$$a = g\,\frac{F\,S}{f\,w}$$

and

$$m\,a = \frac{a\,w}{g} = \frac{F\,S}{f}$$

or, force of inertia $\times f = F \times S$.

In other words: Bending moment due to earthquake impact must equal resisting moment. This coincides exactly with the writer's point of view, and the foregoing computations. These computations apply to a pole with a free end acting as a cantilever under the earthquake transverse force, whereas the walls of a building are tied across by joists or roof trusses which make them act as supported beams. In fact the pillars and columns with flat ends are about an intermediate case between supported and fixed ends, but if they are dealt with as supported ends the results will be on the safe side.

The likelihood of vibration, for different beams, is measured by the deflection taken under similar loading conditions, and, therefore, the deflection ratio will show the ratio of the force of inertia on a cantilever and a simple beam of the same weight, cross-section, and span.

For the sake of comparison, the writer adopted the formulas for deflections of beams under uniformly distributed loads, although the distribution of forces of inertia along the beam is not uniform. In accordance with this principle, if the earthquake impact on a canti-

lever is 9.1 times its weight, the same earthquake impact on a simple beam should be:

$$9.1 \times \frac{8}{76} = \frac{9.1}{9.5} = 0.95 \text{ times its weight.}$$

Although the assumption of simply supported ends for columns and pillars of buildings, as made in the foregoing computation, results on the safe side against the error due to the non-uniform distribution of forces of inertia along the vibrating beams, the theory was not accepted until checked by facts. The necessary confirmation having been found in the damage done by the earthquake to Las Vacas Viaduct, 3 miles east of Guatemala City. This damage consisted in the shearing of some of the sole-plate rivets connecting the trusses to the towers, although none of the trusses was displaced from the supports.

The Las Vacas Viaduct is 743 ft. long, 203 ft. in maximum height, and its weight is 976 tons of structural steel with 166 tons of track material, or a total of 1 142 tons. There are seven towers, the damaged ones being 127 ft. high, which is practically the average.

It might be assumed, therefore, that the weight of the part of the structure straining the sole-plate rivets was one-seventh of the total weight, or 163 tons. There are sixteen sole-plate rivets, $\frac{3}{4}$ in. in diameter, on a tower, with sole-plates $\frac{7}{16}$ in. thick. The ultimate strength of these rivets should be 157 tons at the rate of 30 tons per sq. in. The earthquake impact, according to the foregoing theory, should be $0.95 \times 163 = 155$ tons. It is seen that these two figures practically agree.

Again, since only two towers were damaged, it follows that the strain was not much beyond the breaking point; otherwise, all the forces should have given way. Also, in all probability there were along the viaduct some fixed points, or noduli, as there are along vibrating strings.

As to the analysis of the nature of the strains developed by the earthquake, the writer did not even attempt to undertake it, since such strains are of all kinds, oscillation, trepidation and swirls.

The foregoing refers to the reinforced concrete or steel frame of the buildings, the panel walls of which are brickwork in many cases—the only feasible type of construction in view of the scarcity of cement and steel due to the War. It was quite difficult to determine the earthquake impact on brickwork panels, since the application of the elastic theory

to such a variable material as brickwork is rather uncertain, but for a comparison with other observations they were considered as fixed slabs, since they are held on four sides by concrete pillars and wall-plates. To obtain a simple formula for the deflection of such brick panels, in order to estimate the corresponding earthquake impact, the following theory was applied. From the fundamental equation,

$$\frac{E\,I}{\rho} = M$$

the deflections are proportional to the moments. In ordinary practice it is accepted that the bending moment for a square concrete slab is $M = \frac{W\,l}{20}$, as compared with $M = \frac{W\,l}{10}$ for a beam. That is to say, the bending moment for the slab is half the bending moment for the beam under the same load.

It appears, therefore, to be close enough to assume that the deflection, Δ, for the slab should be half the deflection for a beam with ends fixed, or, say,

$$\Delta = \frac{P\,l^3}{768\,E\,I}.$$

If so, the ratio of the earthquake impact to the weight should be, by comparison with the ratio for a cantilever as obtained in the foregoing, as follows:

$$9.1 \times \frac{8}{768} = 0.09.$$

This agrees quite well with the ratio $\frac{1}{12} = 0.83$, given by the Italian Committee.

A 24-in. wall, assuming its weight to be 150 lb. per cu. ft., should have an earthquake impact per square foot of 25 lb. according to the ratio given by the Italian Committee, or 27 lb. according to the writer's assumptions. Adding a wind pressure of 30 lb. per sq. ft., the distance between the concrete pillars required to prevent the brick panels from collapsing can be computed.

This was done by considering a portion of wall 1 ft. deep, disregarding the slab effect so as to be on the safe side. This section of wall, assumed as a simple beam, would be acted upon by an earthquake impact 0.95 times its weight, and the stress should not exceed the allowable transverse stress, taken as 10 lb. per sq. in. as a conservative value. The

end shear should not go beyond 2 880 lb. and the corresponding weight of wall for half the span should not be more than $\frac{2\,880}{0.95} = 3\,030$ lb. Assuming the weight of 1 lin. ft. of wall 2 ft. thick at 300 lb., it follows that a 20-ft. distance between pillars is perfectly safe.

It might be objected that the weight of roof has been neglected in the previously mentioned calculations, but the writer thinks that such weight rather adds to the stability of the walls by bracing them against each other.

As a matter of fact, the inspection of various ruins proved that, in almost all cases, the gable ends of buildings collapsed while the side-walls supporting the roof trusses remained standing in more or less bad shape, which goes to prove that the roof trusses were more of a help than a weakness, in spite of their weight, which, by the way, was rather great, since before the earthquake practically all the roofs in town were of pantiles.

Finally, sufficient reinforcement was allowed in the concrete wall-plates to make a belt around the buildings and main partitions, the tensile strength of which should prevent cracking at the corners, this having been suggested by S. F. Shaw, M. Am. Soc. C. E., at that time Chief Engineer of the International Railways of Central America.

Although the preceding reasoning and calculations are far from accurate, they agree well with facts, and they were developed with the idea of being on the safe side and within reasonable limits.

Tests of Native Woods.

In connection with the reconstruction work, some tests were made of several kinds of wood which are not commonly used for building purposes, with a view to adopting those passing the tests satisfactorily. The writer thinks the results of his investigation might be of use to engineers in tropical countries, if not as absolute values, at least as a guide.

The investigations were based on some fundamental ideas pointed out in the discussion of a paper by Henry S. Prichard, M. Am. Soc. C. E., on "Faults in the Theory of Flexure",* that is, the transverse deformation of materials depends not only on the strength of fibers themselves, but on the bond between fibers as well, especially in wood,

*Transactions, Am. Soc. C. E., Vol., LXXV, p. 895.

the fibers of which adhere to each other by means of such a variety of cementing substances. Furthermore, some connection between the elasticity of timbers and their durability was sought as a check to supplement the chemical treatment, as explained later.

Among cementing substances, the albuminoids and carbo-hydrates are food for fungi and insects. It was the writer's opinion that all kinds of wood with a high modulus of elasticity, E, as compared with ultimate transverse strength or modulus of rupture, R, which ratio might be called "modulus of brittleness," would contain a large quantity of albuminoids and sugar, and hence attract fungi and insects and cause rapid weakening and decay; also, that there should be some more or less constant ratio between the durability in the ground and the resistance to artificial decay by chemicals. The only chemical available at that time for applying the latter test was the hypo-sulphite of soda commonly used in photography, which was substituted for the sulphite of lime to make paper paste.

By comparing the behavior of some known and some relatively unknown kinds of wood through these tests, the writer expected to arrive at some reasonable conclusions in regard to durability. The rough means of experimenting available at the time make the figures, given later, unsuitable for accurate calculations, but approximate enough as a guide.

The transverse bending strength, R, and the coefficient of elasticity, E, were determined by simply supporting a beam 1 in. square on supports 24 in. apart, the center breaking load consisting of old castings and track bolts, the deflections being measured by a thread stretched between supports. For this case, the ordinary theory of flexure leads to the following expressions:

R = ultimate strength in bending = $36 \times$ center breaking load

$$E = 3\,456 \times \frac{\text{Center load}}{\text{Deflection, in inches}}$$

Four specimens of each kind of wood were tested, the deflections being measured under five different loads for the same specimen. The timbers were unseasoned; in fact, they were samples sent by the proposed contractors.

The chemical treatment was applied by putting a slice, $\frac{1}{4}$ in. thick, of the broken 1-in. beams in a vessel made of a 3-in. nipple closed with

pipe plugs at the ends, the vessel being filled with 75 cu. cm. of a solution of hypo-sulphite of soda with a strength of 36% and 3 cu. cm. of hydro-chloric acid with a density of 1.08. These vessels were enclosed in a cylinder connected to the shop boiler and fitted with a steam gauge to maintain the unit pressure at 45 lb. during 45 hours.

After treatment the specimens were tested with a home-made Vicat needle 1 mm. square, weighing 5½ lb., the penetration of which afforded a comparison between the known and relatively unknown woods.

Each specimen was tested ten times. Most of the native woods that were tested have never been classified, and it is impossible, therefore, to give their scientific names, but engineers who have worked in the tropics will very likely recognize many of them. By comparing the results obtained for the known woods, it was considered that values of the modulus of brittleness under 150 are favorable, as a rule, but for very strong woods, the ultimate transverse strength of which is more than 13 000 lb. per sq. in., values of the modulus of brittleness might be acceptable up to 200.

A needle penetration of less than 2 mm. appeared to be favorable. The strength of chemicals and time of steaming were determined by trial.

The results of the tests are given in Table 1.

TABLE 1.—RESULTS OF TESTS OF TROPICAL WOODS.

Sample No.	Name of wood.	Modulus of rupture, R, in pounds per square inch.	Modulus of elasticity, E, in pounds per square inch.	Modulus of brittleness, $\frac{E}{R}$.	Size of nail splitting specimen.	Needle penetration after treatment, in millimeters
1..	Sangria............	12 736	1 558 000	122	40d.	1.47
2..	Sangre	5 652	1 261 000	223	40d.	6.00
3..	Leche Amarilla ...	10 605	1 819 000	171	20d.	2.30
4..	Santa Maria.......	10 449	1 539 000	147	20d.	1.47
5..	False Fustic.......	12 663	1 862 000	148	20d.	2.30
6..	Fustic..............	14 751	2 702 000	186	16d.	Practically nil.
7..	Hormigo	9 847	1 705 000	173	20d.	1.75
8..	Red chichique.....	11 754	1 857 000	158	20d.	2.20
9..	White chichique...	17 335	4 848 000	279	20d.	6.00
10..	Chichipate	21 474	2 509 000	117	20d.	Practically nil.
11..	Nance	13 167	2 408 000	182	20d.	1.10
12..	Native pitch pine..	8 766	1 582 000	180	30d.	2.40
13..	Campanillo........	16 380	2 339 000	142	16d.	1.30
14..	Güachipilin........	16 587	2 695 000	131	20d.	0.70
15..	Genizaro..........	10 953	1 569 000	144	20d.	1.00
16..	Laurel (Atlantic) .	6 644	958 000	145	40d.	5.00
17..	Black laurel.......	10 278	1 239 000	120	20d.	0.60
18..	Madrecacao	12 285	1 556 000	126	20d.	0.40
19..	Güayacan..........	......	....	...	....	Practically nil.

Sample No. 1, Sangria.—There were contradictory reports about this sample, Sangria, because of different woods with similar names.

Sample No. 2, Sangre.—This is very similar to Sample No. 1, but of a lighter weight and of the undesirable kind; the results of the tests made it possible clearly to differentiate both kinds.

Sample No. 3, Leche Amarilla.—On account of its yellow juice, the third sample had the name "Leche Amarilla". The ultimate transverse strength 10 605 lb. per sq. in. is the average of four specimens, one of which was as low as 7 000 lb.

Sample No. 4, Santa Maria.—Some foundation blocks of Santa Maria were reported to be perfectly sound after five years in the ground.

Sample No. 5, False Mora, or Fustic.—A specimen of an odd wood was received, the sender claiming that it was Mora or Fustic which in the war days was exported as dyewood. The results of the tests are as given in Table 1. The needle penetration of more than 2 mm. and the modulus of brittleness under 150, but very close to it, contradicted the well-known lasting qualities of Fustic. This being the case, the original log was examined by a wood expert and compared with a log of true Fustic, with the result that it was found that the sample was not true Fustic.

Sample No. 6, True Mora, or Fustic.—The results of tests of true Mora or Fustic were as stated in Table 1. The needle penetration was inappreciable and the specimen could not be broken with the fingers as had been done with more or less difficulty with previous samples. This harmonizes with the writer's assumptions and the well-known durability of Fustic, but leads to allowing values up to 200 for $\frac{E}{R}$, if R is more than 13 000.

Sample No. 7, Hormigo.—The sapwood of Hormigo rots out very quickly, although its heartwood has proved satisfactory in actual practice. The specimen used had a fair percentage of sapwood. The modulus of brittleness was rather high, due to the sapwood in the sample, whereas the slice used for chemical treatment was practically all heartwood.

Sample No. 8, Red Chichique; Sample No. 9, White Chichique.—There are two varieties of Chichique, red and white, which lead to contradictory reports. The red variety has a life of, say, 5 years in the ground. The unfavorable results for white Chichique are confirmed by

actual practice, as the white variety is rotten after being 2 years in the ground.

Sample No. 10, Chichipate.—This wood has a very good reputation in actual practice. This specimen was rather well seasoned, as it came from car shop stock.

Sample No. 11, Nance.—This was reported as giving satisfaction in the ground for foundation blocks.

Sample No. 12, Native Pitch Pine.—The penetration was quite variable, sometimes being as much as 3.5 mm. There are reports of some posts of this quality rotting after 2 years in the ground.

Sample No. 13, Campanillo.—This wood has proved to be fairly good in actual practice.

Sample No. 14, Güachipilin.—This wood is very good in actual practice.

Sample No. 15, Genizaro.—This is fairly good in actual practice.

Sample No. 16, Laurel (Atlantic Side).—There is a very good wood called black laurel on the Pacific Coast, and some samples were brought from the Atlantic Coast with the expectation that they would be as good as the others. The tests showed, however, when compared with Sample No. 17, that this expectation was not fulfilled.

Sample No. 17, Black Laurel.—The results for this wood confirmed its lasting qualities and are quite different from the laurel on the Atlantic side, Sample No. 16.

Sample No. 18, Madrecacao.—The results for this wood require no comment.

Sample No. 19, Güayacan (Lignum Vitæ).—No sample of the required dimensions for the physical tests was available, but for the sake of confirming the effectiveness of the chemical treatment, a small sample on hand was subjected to it. The needle penetration was nil.

Several specimens of unknown woods were tested, as well, and by comparison with the results for the samples as listed in Table 1, some reasonable probabilities were obtained as to their lasting qualities, which made it possible to accept or reject them in contracts.

The foregoing tests having been made more than a year ago, sufficient time has not yet elapsed for actual experience to confirm or contradict the results, although they agree fairly well with the information available at the time.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE PROSPECTIVE COMPETITOR METHOD OF VALUATION OF PROPERTY*

By M. L. Byers,† M. Am. Soc. C. E.

Synopsis.

The Courts having ruled that, in estimating the fair value of any operating property, the fact that the property is a going concern must be taken into consideration and that this fact is an element of value, there remains to be devised a method whereby, when the fairness of the rates is in question, this fair value of the property can be estimated with reasonable accuracy.

The method which of late years has found most favor is that usually termed the Cost-of-Reproduction Method. In a general way, value is arrived at by this method about as follows:

From cost of reproduction of the physical property (including a percentage for overhead costs) deduct "depreciation"; to this add going concern value.

The method does not seem to rest on sound economic principles, and parts of the practical operations involved in its use do not appeal to the logical mind. Too much is left to mere personal opinion uncontrolled by guiding principles.

One Court observed that he reluctantly accepted this method because he did not know of a better one. The remark of the Master

* This paper will not be presented for discussion at any meeting of the Society, but written communications on the subject are invited for subsequent publication in *Proceedings*, and with the paper in *Transactions*.

† New York City.

in the recent Denver Water Company Case with reference to going concern value is also illustrative. He states:

"There is no absolute standard by which the fair value of this element can be determined, and I adopt $800 000, because no matter how often I have considered the evidence and the arguments my mind always comes back to this amount as reasonable and fair to all the parties."

Further illustration of the difficulties produced by this method is found in the Minnesota Rate Decisions, in which Justice Hughes pointed out in connection with the valuation of the land of the railway that "the assumption of its [the railway's] non-existence, and at the same time that the values that rest upon it remain unchanged, is impossible and cannot be entertained."

Presumably the reproduction theory may be based on the view that this presents the means of estimating what the property under valuation would have cost to construct and develop if present-day conditions as to prices of labor, material, land, etc., density of population, and similar elements had been present during such period of construction and development. This is merely a variation of the theory that the fair value of the property is measured by the investment, whereas, as a matter of economic fact, there is, in general, no necessary relation whatever between the value and the cost of a property.

What is urgently needed at the present time is a rational method of valuation which is in harmony with sound economic principles and does not clash unnecessarily with well-established legal decisions.

The analysis of a new method of determining the fair value of a railroad property, which follows, is founded on seven basic propositions:

1.—A railroad corporation is a private corporation; its property, although devoted to the service of the public, is private property, and its value is as completely under the protection of the Constitution as that of any other private property.

2.—The property of a railroad corporation devoted to the service of the public, and which has been acquired through gifts or donations, or from earnings, is, equally with property acquired from the proceeds of the sale of securities, private property, and as such is under the protection of the Constitution. The surplus from the earnings of the corporation is likewise private property.

3.—Every enterprise subject to regulation is entitled to be permitted to earn such a return as, in the field of free and open competition, would ordinarily accrue to a similar expenditure of energy, foresight, and capital.

4.—A public utility is not entitled to a return accruable solely because of its possession of monopolistic protection from competition.

5.—Every kind of business, without any exception, has an element of value known as going concern value, and such going value is in no way connected with the monopoly or good will value.

6.—The market value of any property results from the use to which it is put and varies with the profitableness of that use, present and prospective, actual and anticipated. There is no pecuniary value outside of that which results from such use. The amount and profitable character of such use determine the value. The measure of that value is its profitableness, present and prospective, actual and anticipated.

7.—The fair value of a property is measured by its profitableness, present and prospective, actual and anticipated, under fair rates.

The analysis results in the development of the Prospective Competitor Method of valuation. The steps recommended in the case of a valuation of a monopoly by this method are as follows:

1.—Production of a prospective competitor (instead of "reproduction" of the property under valuation).

2.—Determination of the rate level which (within that maximum period of time beyond which capital would not be willing to wait) will enable said competitor to earn a fair return on its investment to date.

3.—Determination of the annual net earnings, as of the date of valuation, of the property under valuation and at the rate level indicated in Item (2).

4.—Capitalization of the annual net earnings indicated in Item (3); this capitalized amount is the fair value of the property under valuation. In the case of properties subject to competition, the fair value of all such properties combined (and which combination, consequently, may be treated as a

monopoly) is first obtained by the preceding method; the common fair rate level is also ascertained. By the application of this rate level to the individual properties, the fair return of each is ascertained. Capitalization of such individual fair return gives the individual fair value.

The Competitor Method practically involves no difficulties which are not met with in the Reproduction Method, while it is logical throughout and is based on sound principles of economics.

I. General Principles and Recommended Procedure.

1.—Railway Valuation, Its Theory and Uses.

For many years the railways have contended that the activities of the Interstate Commerce Commission and of the State Commissions have resulted in the lowering of transportation rates to a point where the prosperity of the industry has been seriously interfered with. The Commissions have always replied to this accusation that, while the railroads certainly are not earning the normal rate of return on their capitalization, they are earning, at the very least a fair rate of return on their fair values; that the real trouble with the railroads is and has been that they are so greatly over-capitalized that a fair charge for transportation produces a comparatively small rate of return on the enormously watered capitalization.

After many years of persistent recommendation on the part of the Interstate Commerce Commission, Congress passed the law calling for valuation of the railroads, which is now in progress. The principal reasons given by the Commission for its recommendation were that the information was needed in connection with the proper execution of the duties of the Commission, and that the controversy over railway values should finally be cleared up in the interest of all parties.

Since the passage of the Valuation Act, numerous comments have been heard at frequent intervals, among these being statements that it is impossible to find the value of a railway property; that the value, being dependent on earnings, is constantly changing, and that the valuation to-day would be out of date to-morrow; that valuation is useless for rate-making purposes, as the rates do not depend in any

way on the value of the property used; that there is no need for the regulation of railway rates, for the reason that the business itself affords a sufficient check over excessive rates (the very great general increase instituted by the Government as a war measure hardly supports this last contention); and that there are a number of values for the same property, depending on the use to which the data are to be put.

Discussion as to what constitutes fair value has been even more interesting, being largely colored by the interests of those entering into such discussion. The representatives of the States have been consistent in their position that it was their duty to see that the public did not have imposed on it a valuation entirely in excess of the equities of the situation. The railroads have been equally energetic in their efforts to see that the resulting valuation did not arrive at an inequitably small result. Apparently, the Division of Valuation of the Interstate Commerce Commission early came to the conclusion that the railroads were amply able, on all proper occasion, to demonstrate clearly the propriety of deciding in their favor any doubtful points, and that the proper policy was to start out with assumptions which would produce the smallest values; then, through hearings before the Division and before the Interstate Commerce Commission, thrash out the points of controversy to an equitable conclusion.

One of the first claims made as to the constitution of "value" was that it was identical with "cost of reproduction" of the existing property, no allowance being made for appreciation in the value of land; the railroads, being public utilities, were assumed not to be entitled to any unearned increment. As this position apparently became legally untenable, and as the items of cost of reproduction ordinarily overlooked by the casual observer became increasingly important, a tendency developed to assert that value equals, not cost of reproduction, but original cost to date of the existing properties.

The effect on value produced by depreciation and appreciation existing in the property has also been widely discussed. Another of the frequently heard statements in connection with the ascertainment of value is that it is not a matter of fixed rules, this quotation from a decision of the Supreme Court being interpreted to the effect that there are no fundamental principles on which the ascertainment of value can be based, thus still further befogging an already complex subject.

In none of the many discussions on the ascertainment of value has there been any complete analysis of the problem, followed by an attempt to work out principles solidly founded on equity and economics. The present discussion is an attempt to analyze the entire problem and then to build up a rational theory of valuation in harmony, if possible, with such legal generalities as so far have been promulgated.

2.—What Is a Public Utility?

Ordinarily, when a public utility is mentioned, it is understood that a utility supplying water, or gas, or electric light, or transportation to a community, and operating under a charter as a corporation, is meant; that other activities such as farming, manufacture of steel, clothing, food, etc., are not so regarded.

There has gradually developed in the public mind a feeling that public utilities because of their being public utilities, are subject to entirely different economic laws and have entirely different legal and moral rights and obligations from those of other forms of commercial activity. This unreasoned feeling has been the cause of much misunderstanding and dissatisfaction and of much ill-advised regulation.

Examined from the broad point of view, almost every form of commercial activity is a public utility. The farmer does not raise the greater portion of his crops for his own use, but for the use of the general public. The manufacturer manufactures his product with the same object in view. The essential difference between the so-called public utilities and other forms of enterprise lies in the fact that, in the case of the public utility, there usually enters the element of monopoly, either because of the physical conditions surrounding it or because it is to the interest of the public that the enterprise shall be conducted without competition.

Perhaps a broad definition for a public utility is that it is any industrial activity conducted on such a large scale or under such conditions that the interests of a considerable portion of the containing community are vitally affected thereby.

Looking to the future—bearing in mind the great strides which have been made during the past fifty years in the organization of various enterprises—it seems probable that, in the not distant future, many other enterprises will have arrived at that perfection of organization

where sufficient control is exercised by a few persons to enable them, if unrestrained, to reap the rewards possible only to monopoly.

It is sometimes stated that an enterprise conducted by a private individual is not subject to Government regulation. This is simply a misstatement of fact. It is also frequently claimed that the giving of the right of eminent domain by the public to certain corporations introduces factors which justify the public in establishing regulations not otherwise equitable. The purpose of the giving of the right of eminent domain has been widely misunderstood and misrepresented. In certain types of industry, in the absence of the right of eminent domain, it would be possible for a single individual to obstruct, or even to prevent entirely, the development of a particular enterprise. Yet it has often been to the public interest to induce private capital to enter such fields. To this end, under various restrictions, the right to condemn property, on payment of fair compensation, has been granted. To claim that the conferring of this right carries with it the privilege of making later exactions on the grantee is as if a householder employed an artisan to do certain work for him in his house, gave him the key to the house in order to enable him to enter therein, and then stated to the artisan that because of having given him the key he is entitled to pay him a smaller compensation than the going rate for such service.

3.—When and Why Regulation of Industrial Activity Becomes Desirable.

Ordinarily, in industrial activity on a considerable scale, there are four important parties at interest, namely, the owner of the activity (the stockholder), the employee, the individual user of the product, and the general public.

Simply in his capacity of owner, the stockholder is interested only in the amount of profit obtainable from his investment, although that interest extends to the broad point of view and is not confined solely to the narrow limit of immediate results.

The employee is primarily interested in the conditions of service under which he is employed and the compensation received for such service.

The individual user of the service is interested in its quality and in the payment which he must make therefor. If the service which he desires is an unusually expensive one, it is to his interest that pay-

ment for such service be based on general averages of cost, rather than on the cost of the individual service itself. For example, the man who lives at one end of the street car line and has his business at the other end, desires that a single average fare be collected from each passenger.

The general public, although less acutely interested than the three other parties, does have a broad general interest of considerable importance. It is to its interest that the relation between productivity and effort expended (such as the amount of capital utilized) in securing the total production, be as favorable as possible, for by improving this ratio the wealth of the community can be increased. The basis of the division of cost of service is also important. Shall the user pay the entire cost of production of that which he uses or shall a portion of this cost be distributed (as by taxes) to the general public? In this connection, the general public must bear in mind that there is frequently an indirect value of the service which it alone receives; for example, the first transcontinental railroad in the United States made possible the development of the Western territories and the knitting together of widely separated populations into a homogeneous community. Lastly, there remains the relation between the character of the industrial activities and the requirement for good government. Will a given policy of industrial activity, if permitted, react on the political security of the community?

Ordinarily, competition and the relatively diminutive character of the individual industrial activity have been found to regulate satisfactorily the relations of the four interested parties mentioned. In the absence of competition, whether due to physical conditions or otherwise, and even in the presence of competition in the case of activities of great importance, some form of artificial regulation of the more or less conflicting interests of the various parties must be resorted to, or abuses will creep in and multiply to the point where dangerous unrest is created, as has been the case in several localities and on several occasions in the transportation industry of the United States.

4.—What Is Valuation and What Are Its Uses in Connection with Industrial Regulation?

The casual observer would be apt to say that valuation is the process of finding value. Such, however, is far from being the entire story.

Valuation is the process of ascertaining one or more of a number of things, among which the following may be mentioned as being the most prominent:

1.—Forced sale value—being the amount in dollars for which a property would sell if thrown on the market, as at sheriff sale.

2.—Market value—being the amount for which a property would sell when the owner is desirous, but not compelled to sell, and when the purchaser is desirous, but not compelled to purchase.

3.—Fair value—being the value for which the property would sell if the commodity rates were fair, if the owner was desirous, but not obliged to sell, and if the buyer was desirous, but not obliged to buy.

4.—Investment to date—being the net amount of capital which has been invested in the property to date, and, consequently, including expenditures for abandoned property and excluding the value of aids, gifts, grants, and donations received.

5.—Original cost to date—being the same as investment to date, except that the expenditure for abandoned property is excluded.

6.—Cost of reproduction—being the estimated cost, under normal conditions as of the date of valuation, of reproducing the existing property.

7.—Physical depreciation—being the percentage of the useful life of the existing property which has been consumed through age and use.

8.—Depreciation of obsolescence and inadequacy—being the percentage of the life of the property, as a whole and for its present uses, which has elapsed.

9.—Tax value—being the amount on which the property is taxed (and depending on the local tax laws).

The principal uses claimed for valuation in connection with industrial regulation are that the data are more or less necessary in order to arrive at equitable conclusions with reference to taxation, to individual rates, to the general rate level, to the amount to be paid in cases of condemnation and sale, to capitalization, and to the giving of needed information to the investor.

5.—What Is Value and How Many Kinds of Value Are There?

It is the fashion in certain circles to speak of value as being a nebulous sort of thing, undefinable and incomprehensible for valuation purposes. It is another example of the cuttle-fish instinct to muddy the water with which the subject of valuation is so frequently approached. The necessary first step in any logical consideration of the subject of valuation is to define clearly this term in its intended uses.

Definition.—Value is a ratio in exchange.

In other words, it is a statement of the number of units of one kind for which a single unit of another kind is exchangeable. It is a mere abstraction and requires the addition of an explanatory and limiting term to make it available for practical use. To illustrate, a diamond may have the same money or pecuniary value as fifty tons of coal, but it has not the heating value of one ton.

The forced-sale value of a property (which is usually adopted as the tax value) is often only half, or less, of the normal fair value where neither buyer nor seller act under compulsion. Also, there is the sentimental value which the owner may place on a commercially worthless heirloom.

Definition.—Pecuniary value is the amount of money a property will sell for when the owner desires, but is not obliged to sell, and the purchaser desires, but is not obliged to buy.

In this discussion, unless specifically stated to the contrary, it is this value that is referred to whenever the term "value" is used.

Evidently (pecuniary) value, as defined, is determined solely by economic considerations.

Definition.—Market value is the value of a property as determined by present and probable future economic conditions.

Regardless of the fairness of the rates in effect in any property subject to regulation, market value is determined by the existence and probable continuance or discontinuance of these rates, and in disregard of their fairness except as this may reflect on their probable permanence.

Definition.—Fair value is the value which a property would have if, for the present rates, fair rates were substituted, with the reasonable certainty that they would continue in the future.

It is evident that there are as many values for a property as there are points of view from which the subject can be approached. For the

purpose of this discussion, value will be limited to that for rate regulation and for condemnation and sale.

6.—Profitableness Under Fair Rates, the Measure of Fair Value.

What is undoubtedly the fundamental economic law to be kept in mind in the valuation of property for condemnation or for rate regulation has been stated by the Supreme Court of the United States, in Cleveland, Cincinnati, Chicago and St. Louis Railway Company *vs.* Backus, 154 U. S. 439, in the following terms:

"But the value of the property results from the use to which it is put and varies with the profitableness of that use, present and prospective, actual and anticipated. There is no pecuniary value outside of that which results from such use. The amount and profitable character of such use determines the value. * * *"

Although it is true that, for a property not subject to regulation, the value at any given time is measured by the profitableness, present and prospective, actual and anticipated, this is not the value (more properly termed the fair value) to be found for use in condemnation or for use with reference to rate regulation. For such purpose, fair value is measured by profitableness, present and prospective, actual and anticipated, under fair rates. If this were not the case, it would be possible, through rate regulation, to reduce the rates and, consequently, the net earnings and the profitableness of the property to any point arbitrarily selected, and then obtain a value for condemnation purposes, based on such unfair rates, which would be far below the fair value of the property. Such a procedure would seem, equitably, to be inconceivable.

The Courts have called attention to the fact that, where the fairness of rates is in doubt, profitableness resulting from such rates cannot properly be used in the determination of fair value. This is axiomatic. The converse is also axiomatic, namely, that where the rates are acknowledged to be fair, the fair value can properly be ascertained by the use of the resulting profitableness as its measure.

As fair value is dependent on fair rates and fair rates on fair value, it would seem immaterial, when neither is known, which is to be ascertained first, except that, contrary to the general view, it is practically much more convenient first to ascertain fair rates and then therefrom to ascertain fair value, than to proceed in the opposite direction.

7.—"Cost" *vs.* Value.

When the fairness of the rates is questioned, it is impossible directly to apply any known variety of profitableness to the measurement of fair value; "cost" in some relation to the property consequently must be used. A brief consideration of several special cases, however, clearly indicates that, in general, there is no necessary fixed relation between the cost of a property and either its market value or its fair value.*

If, therefore, cost is to be used in the determination of fair value, it is necessary that it be applied (1), under such special conditions as shall create a known relation between such cost and the fair value, and (2), where such established relation shall be equitable. Then, wherever such conditions can be simulated, one can properly utilize such variety of cost in the determination of fair value.

Except through occasional accidental coincidence, however, the only circumstances under which cost bears a fixed relation to value are those in which some one having the necessary power decrees that such commodity rates shall be charged that the resultant profitableness will establish this chosen relationship. This can be done in the case of a monopoly, but it is an impossibility in the case of two or more properties subject to competition.†

In order that the owner of a monopoly under regulation shall not be deprived of that protection against confiscation which is guaranteed by the Constitution, the next step is to inquire in what specific case, capable of being simulated under the above circumstances, it is equitable to enforce some relation between cost and value and as to just what this cost and this relation are. This is a problem in economics and economic principles only are involved.

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* A plant for the manufacture of furniture is constructed in the wilderness at a cost of \$100 000. No purchasers can be found for the product and the salvage value of the plant is only \$1 000. Here the relation of cost to value is as 100 to 1. A similar plant is built at the same cost where labor and raw materials are plentiful and where the market is so good that the average profits are \$18 000 per year. If capital is worth 6% per annum, the value of this plant is \$300 000 and the relation of cost to value is as 1 to 3. Between these extremes lie all varieties of relations between cost and value.

† Consider two plants, A and B, in competition. Being in competition, they must adopt the same selling prices, or one would do all the business. Assume that the "cost" of A is \$100 000 and that of B \$200 000; also that, at the present selling prices, A's gross earnings are \$6 000, and his net earnings are \$4 000 per year, while B's gross is \$9 000 and his net \$5 000. Suppose it is decreed that the selling price shall be raised one-third in order that A's net shall become \$6 000. Then B's net becomes \$8 000. Capitalizing, at 6%, A's value becomes $\frac{6\ 000}{0.06} = \$100\ 000$ and equals his "cost", while B's value becomes $\frac{8\ 000}{0.06} = \$133\ 333$ as against a "cost" of \$200 000. No selling price applied to both will give each the same ratio of cost to value.

The owner of every regulated enterprise is entitled to earn the same profit as the same amount of capital, intelligence, and industry would normally enable him to earn in the field of free and open competition.* Therefore, it becomes of fundamental importance to establish the principles under which commodity selling price is determined in the open field of free competition.

8.—The Principles Governing Free Competition—Their Application to Valuation of a Monopoly.

Let us suppose some community is served as to some commodity by a producer whom we will call briefly the A. and B. Company. This company has been in the field for years and has no competition. Local conditions do not prevent competition, and the commodity price is not limited by the public's ability to pay.

Certain capitalists, whom we will call the X. Y. Company, are looking for a favorable opportunity to make investment of their surplus capital. They, of course, have the range of the entire field of investment, regulated and unregulated, foreign and domestic, from which to choose; they will enter that field which, on investigation, gives promise of offering the greatest inducement as to profit, risk considered. Among others, the field occupied by the A. and B. Company comes under their consideration. Their decision as to whether or not to become competitors of the A. and B. Company will be governed by the answer which they accept to the following question:

"Considering the difficulty of establishing a new enterprise in competition with an old, established concern, will it be possible, within a reasonable period of time for such new concern to create a more than normally profitable business, considering the amount of capital which would have to be invested?"

As to the amount of capital necessary to be invested in the proposed new enterprise, the X. Y. Company realizes the following:

1.—Neither the amount of money which it was necessary for the A. and B. Company to invest in its plant, nor the profitableness of that enterprise, has any bearing on the situation.

* To deny this is to establish one of two conditions: If a greater return is allowed, the public is assessed a greater than normal charge for service rendered. If the right to earn at least this amount is denied, and it becomes known that such is the rule, capital cannot be enticed into the enterprise, and it will become dependent on Government ownership or will be destroyed. For it is an unquestionable fact that liquid capital is free and will be invested only where it can obtain at least the normal rate of return, risk considered. The entire field of investment in freely competitive enterprises, at home and abroad, is open to it at all times. It cannot be coerced into entering a regulated field where it will be compelled to accept less than the normal return obtainable in the competitive field.

2.—The X. Y. Company will be obliged to pay present-day prices for the land, labor, and material entering into the construction of its plant.

3.—The possible volume of business is limited in amount; also this total available must be divided with the A. and B. Company, already in the field.

4.—The A. and B. Company cannot secure commodity prices higher than those which the customer can afford to pay; the X. Y. Company cannot secure prices higher than those of the A. and B. Company.

5.—In determining the total amount of capital which the X. Y. Company must invest in its proposed enterprise, there must be included not only the actual expenditures for construction, but also the loss of a normal rate of return on its expenditures during the construction period and during the lean years (the "development period") which must follow, during which its volume of business is being built up to a sufficient density to enable the normal rate of return to be earned on the entire investment.

One of the most common causes of failure of business concerns is insufficient capital; the insufficiency is all too frequently caused by under-estimating the capital requirements of the development period and by failing to provide adequately for contingencies.

In determining the amount of capital necessary in the competition with the A. and B. Company, the X. Y. Company would ordinarily prepare its own plans, estimate the purchase price of the land prospectively required, estimate the construction and operating costs of the prospective plant, etc., in addition to estimating the volume of business and the unit selling price probably obtainable.

As a matter of convenience, however, the X. Y. Company might conclude that it could obtain practically the same construction-cost and operating-cost figures by taking the estimated cost of reproduction of the A. and B. Company's plant under present-day conditions and by using the A. and B. Company's unit operating costs. Herein lies the sole economic justification for accepting "cost of reproduction" as a major element in the determination of value. The X. Y. Company would still be obliged, however, to make an independent estimate, not only of the amount of business which it, the X. Y. Company, as a competitor, could secure, but also of the capital cost to it of its develop-

ment period under these conditions; it could not substitute A. and B. Company data for this purpose and obtain acceptable results.

In the field of free competition, it is the conditions facing the prospective competitor and not the cost of the existing property which control commodity selling price and, consequently, profitableness and value of the latter. The value of any unregulated individual enterprise bears no necessary relation to its cost. For illustration: The cost of a manufacturing plant constructed in the heart of Alaska would be much greater than that of a duplicate plant constructed on a railroad in the State of New York; but the profitableness of the New York plant, and, consequently, its value, would probably be much greater than that of the Alaska plant.

Consideration of the preceding illustration of the working of competition in the regulation of commodity price indicates as follows:

A.—The fair commodity selling price at the time of investigation and in the field occupied by the A. and B. Company is that which is just sufficient to permit a prospective competitor—as the X. Y. Company—a normal rate of return, risk considered, on its necessary capital outlay, this being based on a development period not exceeding that reasonable time which capital would be content to wait for a fair return. For this is a free field, wide open to all competition; this commodity price neither invites competition nor repels it; a higher price established by the A. and B. Company would attract competition, while a lower price would repel it.

B.—The measure of fair value of the A. and B. Company is its profitableness, present and prospective, at this fair commodity selling price—just sufficient to permit a prospective competitor to earn a normal rate of return, risk considered, on its necessary capital outlay.

In valuation in the non-competitive fields, it is proper, therefore, instead of constructing a theoretical "reproduced property" as is sometimes suggested, to construct a theoretical "prospective competitor". Thereby the conditions governing commodity price in the competitive fields are simulated and the way is thus opened to estimate fair commodity price and fair value of the property under valuation.

It is to be noted that the illustration, and, consequently, the principles deduced therefrom, refer only to the case where the existing company has no competitor; in other words, it is a monopoly, though

able to remain so only by not charging unfair prices for its commodities.

9.—Method of Estimating the Fair Value of an Enterprise Subject to Competition.

Where the valuation of competitive properties is at issue, the same principles can be applied by first considering all the competitive properties as a single unit, such unit being, of course, a monopoly of the type used in the illustration. In this manner, through resort to the use of the prospective competitor for this monopoly, the fair commodity price and the sum of the fair values of all the competitors are obtained.

The problem still to be solved is, having estimated the sum of the fair profitableness and of the fair values of the properties regarded as a unit, and having records showing their present and past individual operating statistics, how to find their individual fair values.

The first step is to compare the sum of the fair profitableness with the sum of the normal actual profitableness and ascertain the percentage by which the actual must be raised or lowered to equal the fair profitableness. Next, apply this percentage as a correction to each individual normal actual profitableness in order to obtain its fair profitableness; from this, compute fair value by capitalizing at the normal rate of return, risk considered, in such industry. For example, three railroads—A, B, and C—are in competition in a certain district; they have present gross earnings of $10 000 000 and net earnings of $4 000 000, divided between them, as shown in Table 1.

TABLE 1.

Road. (1)	Actual gross. (2)	Actual net. (3)	Fair net. (4)	Fair value at 6 per cent. (5)
A	$2 000 000	$800 000	$1 000 000	$16 667 000
B	3 000 000	950 000	1 250 000	20 833 000
C	5 000 000	2 250 000	2 750 000	45 833 000
Total........	$10 000 000	$4 000 000	$5 000 000	$83 333 000

Assume that valuation indicated that the total fair profitableness of the three railroads should be $5 000 000 instead of $4 000 000. In order to increase the net of $4 000 000 to $5 000 000, it will be necessary to

increase the gross earnings $1 000 000, or 10%, this being brought about by a 10% raise in the general rate level. Adding 10% of its gross earnings to the present net earnings of each railroad gives the fair net, as shown in Table 1, Column 4. This amount capitalized at 6% indicates a fair value, as shown in Column 5. If an individual rate, being too high, is lowered, this merely requires that slightly more than 10% be added to the other rates to produce the necessary fair gross earnings.

10.—Assumptions and Mode of Procedure in the Determination of the Fair Value of a Monopoly Railroad.

In devising the various assumptions which must be adopted, in the "competitor" method of estimating fair value, two fundamental facts should be kept constantly in view as a guide, namely:

1.—The object of the resort to the theoretical "prospective competitor" is to simulate, for the property under valuation, the condition which would normally be produced if that monopoly were actually subject to normal free competition, and thereby to make possible an estimate of what its profitableness, under such conditions, would be.

2.—It is evident that the entire economic justification for the use of cost of reproduction as one element in the determination of value lies in that, if properly used, it ordinarily gives practically the same results as would be obtained from an out-and-out new estimate of the cost of construction of a prospective competitive plant; the assumption must, consequently, always be made with this fact in view.

A.—Assumptions.—

Assumption 1.—The prospective competitor has the same accessibility to all sources of revenue as the property under valuation. In other words, it can, when properly seasoned, offer to the customers of the monopoly exactly the same facilities as those offered by the monopoly. To illustrate, the company under valuation has certain traffic agreements with its connections; the prospective competitor must be assumed, at the cost of a reasonable amount of negotiation, to secure the same terms. The old company reaches a great manufacturing plant by means of a track located through the only available route; the competitor must be assumed to be able to reach the same plant at "cost of reproduction" of the old company's track.

Assumption 2.—The development of the earning power of the competitor will occur through competition, under normal conditions, with the monopoly under valuation, for all the available business, present and prospective.

Inasmuch as the competitor, when properly seasoned, is able to offer the same inducements as can be offered by the property under valuation, it would ordinarily appear that, shortly after the commencement of its operation, the competitor should divide equally with the property under valuation the then business of the latter. Thereafter, the normal rate of growth of business in the industry, in recent years, is the rate of growth to be assumed for the business of the competitor, for the reason that one of the objects to be accomplished is the reduction of development cost to a normal basis regardless of the history of the individual enterprise (usually a history of small enterprises, failing, re-organized, combined, and re-combined over long periods of time).

Assumption 3.—The construction of the competitor's plant will be carried out under present-day methods, at present-day normal prices and under present-day legal and economic conditions. The dates of construction of the individual pieces of property will be selected so as economically to harmonize with the needs indicated by the programme of development of its earning power.

Except as can clearly be shown would be carried out otherwise under the present-day conditions confronting the competitor, the physical characteristics, and, consequently, the construction quantities, including land, of the competitor are taken as ultimately identical with those of the monopoly under valuation. Construction evidently economically greatly in excess of requirements would be developed piecemeal as required. Thus, the competitor railroad would ultimately have the same length of line, grades, curvature, quantities of grading, etc., as the railroad under valuation, but the structure built of materials no longer available would be reproduced with accessible materials of equal suitability.

Assumption 4.—The naked land value of the lands adjacent to those required by the competitor will be the same, in each case, as the naked land value of the lands adjacent to the lands of the monopoly. The improvements assumed to be resting on the land required for the competitor are of the same character and value per acre as those on similar lands in the general vicinity, but not necessarily adjoining the monop-

oly's local facilities. The right of a competitor to use public streets would, or would not, be paid for, according as present-day practices in the community dictate.

Assumption 5.—The competitor will be obliged to pay for its land whatever amounts experience teaches would ordinarily have to be paid, in such communities, by railroads, for lands having naked land values equal to those surrounding the lands of the old company. These prices would include payments account severance and other damages.

B.—Mode of Procedure.—

1.—A programme showing in commodities, not in dollars, the estimated gross business of the competitor, year by year, will be developed for a period sufficiently long to equal, at its end, the normal business of the property under valuation, as of the date of valuation.

2.—A construction cost programme based, in general, on the reproduction of the existing properties of the monopoly under valuation, but at a rate and in an order harmonizing economically with the adopted traffic programme of the competitor, will next be made.

3.—An operating cost programme showing year by year the competitor's estimated gross operating costs, will next be constructed. There must be included in operating expenses a proper annual allowance for deterioration, obsolescence, abandoned property, maintenance, taxes, and rentals accruing after the commencement of operation; amounts accruing before this date are a proper addition to construction costs.

4.—Tables of annual gross and net earnings of the competitor should next be prepared. The rate level to be used in estimating the competitor's gross earnings is the lowest rate level which, within that reasonable time which capital would be contented to wait, will produce net earnings for the competitor equal to a fair return on the competitor's cost to date.

5.—From the preceding, the final table showing the competitor's estimated cost to date for each year and including loss of interest during construction and loss of fair return during operation can be prepared.

6.—Having found the proper general rate level for use in estimating the prospective competitor's gross earnings, the fair value of the property under valuation is obtained by capitalizing its profitableness at this same rate level.

II. General Discussion of Miscellaneous Subjects.

1. Summary of Important Principles Enunciated by the Courts with Reference to Fair Value and Fair Return.

The essential principles enunciated by the Courts with reference to fair value and fair return can be summarized as follows:

1.—What the company is entitled to ask in order that it may have just compensation, is a fair return on the fair or reasonable value of that which is at the time utilized for the public convenience.

2.—On the other hand, what the public is entitled to demand is that no more than a reasonable compensation shall be exacted for the service performed.

3.—The public does not underwrite unwise or improvident expenditures; such expenditures do not add to the fair or reasonable value of any property and the company cannot demand of the public that it be compensated for them.

We still are left by these decisions to discover the principles on which a proper method can be based for ascertaining (1), what is the fair value of the property of the company as used; and (2), what is a reasonable compensation for the service performed.

Nor does the following from San Diego Land and Town Company *vs.* Jasper, materially forward the investigation:

"The ascertainment of that value is not controlled by artificial rules. It is not a matter of formulas, but there must be a reasonable judgment having its basis in a proper consideration of all relevant facts. The scope of the inquiry was thus broadly described in Smyth *vs.* Ames, 'in order to ascertain that value, the original cost of construction, the amount expended in permanent improvements, the amount and market value of its bonds and stock, the present as compared with the original cost of construction, the probable earning capacity under particular rates prescribed by statute, and the sum required to meet operating expenses, are all matters for consideration, and are to be given such weight as may be just and right in each case. We do not say that there may not be other matters to be regarded in estimating the value of the property.'"

2.—That Reasonable Compensation to Which Rates Are to Be Limited.

Most enterprises under regulation differ from those operating in a free competitive field in that the former, to a greater or less extent, are

protected from competition by the interposition of various physical and legal barriers. Thus, a water-works may be protected from competition by legislative enactment, or it may be protected through ownership of the only reasonably available source of supply.

Reading between the lines of the Court decisions with reference to the fairness of individual cases of rate regulation, a broad guiding principle which seems to have been kept in mind is that the ruling should be such as to deprive the regulated enterprise of the benefits of any monopolistic protection and to permit of the earning only of such a return as, in the field of free and open competition, would ordinarily accrue to a similar expenditure of energy, foresight and capital. This is well illustrated by the remark of Justice Holmes in Cedar Rapids Gas Company *vs.* Cedar Rapids, that what the Court excluded was good will or advantage incident to the possession of a monopoly so far as might be supposed to give the plaintiff the power to charge more than a reasonable price. The following may aid in illustration:

1. Assume that a certain farmer takes his wheat to Chicago and demands for it $3 per bushel. Is that an unreasonable price? No, not if he can get it, for this is a free, competitive market; if the circumstances did not justify the price, others would fill the demand at a lower price, compelling him also to lower his price or keep his wheat.

2. A certain community obtains its water supply from a lake 10 miles distant, hauling by wagon at a cost of $1 per 1 000 gal. The A. and B. Company builds a pipe line and delivers water to the town at a cost, including normal rate of profit, of 10 cents per 1 000 gal.; it charges 50 cents, making a very high return on the investment. The quantity of water consumed by the town is so small, however, that no rival entering the field and dividing the demand with the present company could furnish water profitably for less than 55 cents. Is the 50-cent rate unreasonable? No, because the business is freely competitive; as the demand increases, the company will be obliged to lower its rates to prevent competition. Meanwhile, the company, by its enterprise, is performing a public service by saving to the town 50 cents on each 1 000 gal. consumed as compared with the cost under the old method of haul.

3. Suppose that, in the preceding case, the A. and B. Company buys the water supply and thus renders competition difficult, as the next source of supply is 20 miles away. Because of the distance—20 miles—

and the small demand of the town, it would cost the X. Y. Company 80 cents per 1 000 gal. to deliver water at a normal profit. Would it be reasonable for the A. and B. Company to charge 75 cents under these circumstances? The charge would be unreasonable because it is now based, not on that which would be established if competition prevailed, but, on the contrary, on the holding of a monopoly of the water supply in the vicinity.

4. A railroad was built from the City of A into certain undeveloped coalfields at B; *en route* it passes through a gorge which furnishes the only low-grade line across the mountain between the two points. As it completely occupies the gorge, no other railroad can be built, except at a prohibitive cost, over the mountains. A transportation charge which would net 6% on the cost of any line over the mountain would pay 20% on the cost of the gorge route. Owing to the absence of other coalfields in the vicinity, coal could be moved at a profit even at this high charge. Would the charge under these conditions be unfair? The charge would be unfair because it is based on a monopoly of the gorge route, and not on rates which competition would establish in the absence of this physical barrier.

The frequently recurring statement in the older decisions that "a public service company cannot lawfully charge more than the services are reasonably worth to the public as individuals" becomes an absurdity if literally interpreted. Suppose, that, for example, the market for lumber on the A. and B. Railroad is at B and is $10 per 1 000 ft.; a farmer owns timber some miles from the railroad at A, its distance from the railroad being so great that the cost of cutting and hauling to the railroad is $10 per 1 000 ft., being just equal to the price which he would receive for the timber if delivered to the market at B. Inasmuch as there would be no profit to him in the transaction, the value to him of the service performed by the railroad company in hauling his timber from A to B would be nothing; consequently, under the literal interpretation of the decision, the railroad company could make no charge for the service, because it possessed no value to the owner of the shipment.

In the later decisions of the Courts, it has evidently been recognized that rates, to be fair, must be fair to both parties to the transaction, and that the statement as to the value of the service is meaningless; it is consequently omitted. Thus, in Darnell *vs.* Edwards, 244 U. S.

564, the Court, while pointing out that the public should not be compelled to pay rates based on extravagant expenditures, states: "In determining whether rates are confiscatory, because not yielding a proper return, the basis of calculation is the fair value of the property used in the service of the public."

3.—The Fair Value of a Property Subject to Rate Regulation Is the Same for Condemnation as for Rate Regulation.

The well-known principle of law to be observed in condemnation cases is that the fair price to be paid the owner is that on which a buyer, desiring but not compelled to buy, would agree with a seller, desiring but not compelled to sell. The basis of agreement between the buyer and the seller, in such cases, is a conscious or unconscious meeting of their minds as to the profitableness, present and prospective, actual and anticipated, of the property under discussion and a translation of this into terms of value.

Where the property is subject to rate regulation and where, therefore, the profitableness can be varied by regulating the rates, it is evident that this rule must be modified so that it calls for a meeting of the minds of the prospective buyer and the prospective seller, based on their views of profitableness under fair rates.

In case of rate regulation, the owner is entitled to such rates as will enable him to earn a fair return on the fair value of his property. The measure of the fair value of his property is evidently the profitableness under fair rates, but this is identical with the fair value as determined by the previously mentioned rule to be observed in condemnation where rate regulation is in effect.

It is assumed, of course, that the same property is the subject of consideration in each case and that, if only the portion of the property used for carrier purposes is considered for rate regulation, the same (and not also all the non-carrier property) will be the subject of consideration for condemnation.

4.—The General Rate Level (and not Individual Rates) Is the Subject of the Inquiry in the Determination of Fair Value of a Railway Property.

The movement of bituminous coal to the Lake ports furnishes an excellent illustration of the situation to be dealt with in the consid-

eration of individual rates. Coals for the Lake ports are obtained from the coalfields of Ohio, Indiana, Illinois, West Virginia, and Kentucky. The length of haul varies from a few miles to several hundred miles; also, the cost of transportation per ton-mile varies because of variations in grades, size of engine, etc. The quality of the coal, and, consequently, the selling price at the Lake port, varies with the different fields. The cost of production of the coal at the mines varies because of differences in rate of pay of the miners, thickness of vein, relative quantity of slate, etc. A uniform rate per ton-mile would drive some of the more distant fields out of the market. The situation resolves itself into this, that, with a fixed coal selling price per ton at the Lake port, the profit on the total operation involved is to be divided between the owner of the coal, the coal miner, the coal operator, the transporter, and the distributor, on some equitable basis.

It is evident that the position taken by so many of those engaged in the regulation of rates, to the effect that the fair value of the property used is not the principal factor and is often not even an important factor in the determination of fair rates, is entirely correct when limited to the consideration of individual rates. For the purpose of obtaining the fair value of the property used for the public, fair profitableness is the only true measure of such fair value. Fair profitableness, however, in turn depends on, not the fairness of the individual rate, but the fairness of the general rate level. In such valuation work, it can be assumed that all the individual rates are equally fair, or unfair, to the carrier and that, consequently, the raising or lowering of the average rate level by an uniform percentage, is the remedy for unfairness, if such exists. The fairness, or unfairness, of the average rate level is determined by the one consideration that it will, or will not, afford a fair return on the fair value of the property used for the public.

Fair value, therefore, becomes an indispensable factor in the determination of the fairness of the general rate level.

5.—The Relation of Risk to Rate of Return.

Liquid capital, in its choice of a field of investment, cannot be coerced; the direction of its movement is controlled solely by economic conditions. Provided it is merely a risk and not the certainty of loss, capital in seeking investment is not primarily concerned at the pres-

ence of risk, for it is able to protect itself by varying the rate of premium demanded.

No man makes his individual investment on any other basis than the hope that his particular investment is to be numbered among the successful ones. Many prove unsuccessful, however, and these failures, becoming more or less known, produce fear, great or little, according to their ratio to the successes. This fear must be overbalanced by the offer of a premium over safe investment rate. This premium is in the form of the known high profit made by the successes. If the premium does not appear to be high enough, the investor goes elsewhere.

In order that capital shall continue to enter a given industry, it is necessary that the return, risk considered, on capital invested in the industry as a whole must equal the return from investment in other industries. This is a matter of fundamental economic law and is not permanently susceptible of modification by Court or Commission.

Suppose that, from the beginning, a single capitalist had furnished all the capital for each and every individual enterprise in a given industry; one in ten of his investments, measured by the amount of capital invested, proved failures, and the capital invested therein has been destroyed; the remainder are still live enterprises producing various degrees of return (or even loss) on the investment. In order that the capitalist shall be as well off to-day as if he had simply deposited his capital in a savings bank at 3% interest, he must have received from the successful industries a return on his total investment equal to 3% per year plus the amount of capital destroyed to date. Stated differently, he must have received each year on the total capital invested in still living enterprises a rate equal to the rate of return on safe investment plus the annual rate of destruction of capital in the industry.

If regulation holds the rate below this economic level, it may be possible for a time to entice unwary investors into the industry; sooner or later, however, its rate of development will be retarded if not destroyed. To hasten development, rates must be above normal. If the risks of the industry vary in different sections of the country, the rate of return will likewise have to vary, or those sections where the risk is greatest will suffer.

6.—How Can the Fair Rate of Return on the Fair Value of Property be Ascertained?

Most railroad property is owned by corporations whose securities are more or less actively traded in on the stock exchanges of the country; consequently, the current prices can be ascertained with little difficulty. Also, the records of the corporation show the amount of such securities outstanding from time to time in the hands of the public. The current prices multiplied by the amount outstanding give the public's opinion from time to time as to the market value of such property. The net earnings of the property from time to time are also ascertainable from the records of the corporation. Both the net earnings and the public's opinion as to market value are constantly fluctuating, but if we take average figures for each over a considerable period of time and divide the average net earnings (profitableness) by the average market value, the result will closely approximate the rate of return which, risk considered, the public demands on railroad securities before it will invest in them.

7.—General Observations on the Valuation of Properties Subject to Competition.

The presence of competitors greatly complicates the problem of valuation, for the reason that there are, in such cases, many intangible factors which affect profitableness and which cannot properly be overlooked. For example, suppose all the railroads in a certain self-contained district were owned and operated as a single property. The methods suggested for the valuation of a monopoly could readily be applied. Suppose, however, this single railway system is split up into several more or less competing systems under different ownership and operation. It still holds true that profitableness under fair rates is the measure of fair value in each individual case; but how shall we compute this profitableness?

In the case of a railroad forming a part of a group in which the lines are in competition, one with the other, some of the elements which affect profitableness are:

Affecting Number of Units of Output.—

Length of road;

Density and character of adjacent population;

Number and character of industries adjacent;
Traffic production or absorption capacity of connections;
Traffic capacity of the railroad—number of main tracks, character and size of terminals, number, character, and size of available equipment, etc.

Affecting Unit Price of Output.—

Rate regulation;
Length of haul;
Character of product transported;
Intensity of competition;
Percentage of through rate secured, etc.

Affecting Unit Cost of Output.—

Maximum grades and curvature;
Length of haul;
Character of product;
Character of equipment;
Adequacy of facilities;
Density of traffic;
Character of agreement affecting interchange of traffic, etc.;
Regulations affecting quality of service, etc.

Miscellaneous.—It is usually customary to enumerate among the things which make profitableness possible:

The presence of the physical property;
The possession of a franchise permitting of the operation of such property;
The fact that the period has already been passed through during which occurs the development of business to the point where its volume is sufficient for fair profitableness (this is usually called "going concern value");
The fact that the property has been constructed so as to permit of unity of use and connected operation instead of being constructed so that it cannot be so used or operated;
The fact that the management has created friends who become the customers and thus the source of revenue of the property.

Remembering that value is measured by profitableness, the value to an individual railroad of the possession by such railroad of the various elements of profitableness (and, therefore, of value) is measured, in the case of each such element, by the effect produced by the presence of such element on the total profitableness of the railroad. These various elements can affect the profitableness of the railroad as a whole only by increasing earnings or by reducing expenses or both. In order, therefore, to compute value in this manner, it is necessary to compute separately for each element of value of the property, its effect on earnings and expenses (and, consequently, on profitableness).

To attempt thus to compute value by separately computing what part of the total value inheres in each of the various elements of value previously enumerated (and the many others which are suggested by such enumeration) is evidently to become involved in a hopeless mass of detail from which useful results cannot emerge. It would be useless to attempt to compute the value of a few of these elements unless the value of the sum of the remainder is known.

The composite effect of all of the various elements of value possessed by the individual railroad property is accurately weighed and registered in the profitableness resulting from operation under the existing conditions. This, however, merely gives market value and not necessarily fair value (which would be measured by profitableness, present and prospective, under fair commodity rates). How then shall we proceed to estimate fair value?

One suggestion advanced is that, in such case, fair value equals cost plus "other values and elements of value". The only true measure of value is profitableness. The profitableness of an individual railroad, subject to competition, bears no necessary relation, and can be made to bear no fixed relation, to cost. Therefore, to state that the value of such a property is equal to its "cost" plus "other values and elements of value" does not in any way advance the process of computing such value. It is merely equivalent to stating that the weight of a steer equals 500 lb. plus certain other weights yet to be ascertained.

8.—The Relation of Depreciation and of Appreciation to Fair Value.

Depreciation is a lessening in value as compared with value under the basic condition (called "new"); depreciation is brought about by any cause which reduces profitableness, present or prospective. Appre-

ciation is the opposite of depreciation; it may be regarded as negative depreciation.

Solidification of roadbed, grassing of slopes, etc., adjustment of working parts of machinery, etc., reduce future maintenance costs; development of traffic increases net earnings; both, therefore, add to the profitableness and thus produce appreciation in value.

Physical deterioration, obsolescence, and inadequacy affect profitableness by, at some future time, increasing gross expenses as compared with the gross expenses necessary in the absence of such conditions and so produce depreciation in value. The usual remedial process is the replacement of certain portions of the original property at the cost of the expenditure involved in restoring original conditions. This expenditure is usually termed "maintenance cost". Under certain conditions, this cost matures at regular intervals in amounts which are not embarrassing. Under other conditions, the increased cost accrues over long periods of time until, at maturity, it assumes proportions which may produce disastrous results in three ways, namely:

The treasury of the enterprise may suddenly be called on for large sums which it may not be in a position readily to supply and which, therefore, might involve the enterprise in financial difficulties.

This gradual accrual may not become apparent in the ordinary annual reports of the corporation to its stockholders. These stockholders, as well as intending stockholders, basing their estimates of value of the property on the reported past net earnings, form an entirely erroneous conclusion, because they do not realize that the future earning power will be much diminished when it becomes necessary to make the renewals required on account of the heavy accruals of deterioration.

If the commodity rates are under regulation and subject to frequent adjustment, the fluctuations of earning power brought about by gradual accrual and sudden maturity of deterioration, cause an unequal distribution of the production cost among early and late purchasers of the product.

For these reasons it has become customary, from time to time, to include in operating expenses an amount for "depreciation", more or less approximating the annual accrual. These amounts of "depreciation" are included in current operating expenses and a book credit is set up, against which credit the actual expenditures to remove matured

deterioration are charged as they occur. Sometimes, in addition to the mere bookkeeping, an actual fund is created, segregating the amount charged to "depreciation" from the other gross earnings of the corporations, thus establishing a more complete protection.

Various methods have been proposed for estimating the amount of accrual of deterioration, which approximate more or less closely to the actual accrual. The object in each case is the same, namely, to distribute maintenance cost more uniformly than if only expenditures for replacement of matured deterioration were charged thereto.

It is evident that the item which is a final charge to maintenance expense is the cost of removal of deterioration (or "depreciation") and not the deterioration itself, which latter is a condition and not an expense.

In the absence of removal, the present worth of the future cost of such removal is evidently the measure of the depreciation in value as compared with the value if the removal had already been completed, all other conditions remaining unaltered. It is to be observed that, in properties made up of great numbers of articles, as the ties in a railroad track, there is a constant tendency of the amount of deterioration —of the loss of useful life—to reach 50% and to remain constant at that level. Such deterioration in the property as a whole never is removed—the property is designed so as to be really in normal use-condition only when this status is reached—and there is, consequently, no future cost of removal to consider and of which to compute the present worth.

In the case of appreciation, removal thereof is neither necessary nor desirable; nevertheless, the production of the appreciation, whether voluntarily or involuntarily, has usually been accompanied, in some form, by cost; this cost is either chargeable to maintenance or operating expenses, or it must be regarded as a capital expense incurred in the building up of the property to its present condition. As a matter of fact, the cost of that appreciation which takes the form of solidification of roadbed and ballast, grassing of right of way, adjustment of working parts of machinery, etc., ordinarily enters into operating expenses in railroad accounting and can be segregated only with difficulty, if at all, from the other items of operating expense, making it difficult to treat as a capital expense item.

Under the "competitor" method suggested for finding the value of a property, the first step is to estimate that fair rate level which, within that reasonable time which capital would be willing to wait, will produce net earnings for the competitor equal to a fair return on the competitor's cost to date. In order to estimate this rate level, it is necessary to estimate, over a period of years, the gross and net earnings of the competitor. Whatever method of computing "depreciation" is in use on the property under valuation, should be applied to the estimating of the maintenance cost of the competitor during the period of years used for the determination of the fair rate level. Having in this manner determined the fair rate level, the next step is to estimate the profitableness, present and prospective, under the application of such rate level, of the property under valuation; this involves the estimating of the gross and net earnings, under such rate level, of the property under valuation. Here, again, the same rules with regard to the computation of "depreciation" should be applied to the estimation of operating expenses during such period, bearing in mind, also, the physical condition of the property and the probable desirability of increasing or decreasing the normal "depreciation" rate on account of such physical condition.

Attention is called to the fact that it is not directly the physical condition of the property which affects its value but, on the contrary, it is the effect of such physical condition on present and future operating expenses which influences value. It is probable that, under the valuation method proposed, it does not seriously modify the result whichever of the various "depreciation" rules is adopted in the computation, provided the rule is sufficiently accurate to produce, in the long run, a close approximation to actual maintenance expenditures and not, on the contrary, gradually pile up a considerable surplus or deficit.

9.—The Relation of Abandoned Property to Fair Value.

As it is the value of the property at present used for corporate purposes which is to be obtained, and as the value of such property is entirely independent of the amount of the property abandoned, it is evident that such abandoned property is to be ignored in arriving at fair value.

However, if the abandonment resulted from unavoidable causes, such as normal obsolescence, etc., the relation between the cost of the

property abandoned and the cost of the remaining property still in use is of interest, because of the light it throws on what is a fair rate of return in the industry in question. Fair rate of return is made up of two factors, rate of return in the absence of risk, and insurance premium to cover risk. The relation between abandoned property and the total property furnishes an indication of the degree of risk. Also, the subject is of considerable interest in connection with the establishment of rules governing the application of depreciation.

It may be well here to remark that it is only the value of the remaining useful life which is abandoned and that, in practice, this is generally reduced to a minimum by neglecting repairs for some time previous to abandonment and while still keeping the property in service.

10.—The Relation of Aids, Gifts, Grants, and Donations to Fair Value.

In practically all cases, the object of gifts, grants, etc., in whatever form these have been made, has been to induce capital to undertake an adventure in which the risk was otherwise prohibitively high. This additional inducement was really in the nature of a capitalized payment of an extraordinary insurance premium.

If, in valuation for the purpose of determining fair return, the value of the gifts should be excluded, then the effect of the gift is merely to put the giver in the position of being a silent partner in the business without in any way reducing the risk of the other partners; yet this reduction of risk was the primary object of the gift.

For example: The estimated cost of a project is $10 000 000 and it is further estimated that, under the commodity rates which must be used, the profitableness of the enterprise will not be more than $400 000, and may be less. As it is impossible to interest capital in an uncertainty with a maximum return of only 4%, certain outside parties, expecting great indirect benefit from the development of the industry, donate $5 000 000 to the corporation formed therefor. This means that the stockholders will be obliged to contribute only $5 000 000 instead of $10 000 000, while the plant which they will own will have cost $10 000 000 to produce. On the assumption that they will be permitted to have the entire return from the $10 000 000 investment, the probable return on the stockholders' investment of $5 000 000, therefore, becomes 8 per cent. If, on the contrary, the industry is to be subject to regulation and, because of the $5 000 000 donation, the rates

are to be cut to the point where only $200 000 is allowed to be earned, it is evident that the stockholders have not been benefited in any way by the donation, for their risk has not been reduced in intensity and they are still limited to a prospective maximum of 4% on their investment.

Under the method of valuation suggested, it is evidently of no concern to the prospective competitor whether the existing enterprise bought, begged, or stole its now owned property. It is the cost of developing and operating the competitor's plant which must determine the rate necessary to enable it to compete. Fair value of the property under valuation will be determined by its profitableness at this rate.

11.—The Relation of Property Owned but not Used by the Owner in the Public Service, to Fair Value.

It is self-evident that such property should not be included in the value on which fair return is to be allowed. It is to be regarded merely as an investment in which the public has no interest, and any returns from which should be excluded from operating revenue.

It is frequently necessary, however, especially in rapidly growing communities, to look well ahead of the present needs. This sometimes raises the question whether the property is or is not properly to be included in the valuation.

12.—The Relation of Property Used but not Owned to Fair Value.

The value of such property to the user is reflected in the net earnings directly and indirectly accruing from such use. Ordinarily, the gross earnings from such a property are included with the gross earnings from other properties in such manner as to make segregation practically impossible. Under such circumstances, the simplest method of handling for valuation purposes is to include in operating expenses the rental of such property, excluding the item entirely from the reproduction inventory; in some special cases it may be necessary to consider whether or not the terms of the rental are fair, or whether they represent unwise and improvident management, the results from which the public does not subscribe to.

Where it is possible to segregate from other sources of revenue the earnings accruing from the rental of a property not owned but used in the public service, and where the property bears a sufficiently impor-

tant relation to the remainder of the property under valuation, then it can be valued in the same manner as if owned and used. In this case, however, the rental must be excluded from consideration as earnings.

13.—The Relation of Property Owned and Used Jointly to Fair Value.

Recalling that the only true measure of value is profitableness, it is evident that the value to each of the users of a property utilized jointly is measured by the profitableness (gross earnings less gross expenses) accruing to the user from such property, regardless of the terms of ownership. Ordinarily, as the gross earnings accruing directly and indirectly from the use of such a property cannot be segregated from those accruing from other sources, the simplest method of valuation is to include in the gross expenses of each owner its proportion of the expenditures incurred on account of such use. The reproduction cost of the property is pro-rated to the different owners on this or other equitable percentage basis. Where the jointly used property is separately operated and the terms of ownership include the basis of distribution of profit or loss from such operation, the valuation of the jointly used property can be independently made and pro-rated to the users on the basis of the contract basis of distribution of profitableness

14.—When Does "Construction" End and "Operation" Begin?

In the determination of the competitor's investment to date and the commodity price necessary to the securing of a fair return thereon, a clear understanding of the physical and accounting procedures involved, is necessary.

The construction and development of a railroad property to the point where it is a paying going concern involves the following steps: First, the inception of the project and such preliminary promotion and financing as will permit of general investigation and incorporation of the project; second, the securing of sufficient capital to enable the preliminary and location surveys to be made and construction to be commenced. In most cases the purchase of right of way must slightly precede, locally, the commencement of construction. With the continuance of construction, additional capital must be secured. Finally, the point is reached where trains hauling passengers and freight are run, thus enabling capital to be secured from the sale of transportation as well as from the issuance of stocks and bonds.

With the beginning of construction, the processes of solidification, seasoning, and deterioration commence, and these processes increase in rapidity of action with the commencement of train service, thus necessitating expenditures for maintenance of the property already created; embankments settle and are partly destroyed through the action of the elements; grasses, etc., begin to cover the exposed surfaces; decay and wear begin to produce the necessity for later replacement. Meanwhile, construction continues; expenditures for operation and maintenance increase, and the density of train service and of traffic increases.

A time finally comes when it is arbitrarily stated that construction has been completed and that operation of the property has commenced. The failure to recognize that this dividing line is an absolutely arbitrary one, adopted merely for the purpose of facilitating organization matters, including the application of certain accounting rules, and having no relation whatever either to the cost or to the value of the property, leads to confusion in connection with valuation. The continuance of construction which, on ordinary railroads, never actually comes to a state of completion, is now called "additions and betterments"; in some cases it is called "maintenance". In ordinary accounting rules, there is considered to be a great distinction between construction, additions and betterments, operation and maintenance, and "depreciation". For valuation purposes much confusion is avoided if all these terms are entirely disregarded and if, in their stead, the receipts and expenditures necessary to the full development of the property are directly considered without first subjecting them to such misleading classification. In this way the arbitrarily established dividing line between receipts, depending on their sources, and between costs, depending on the instruments used in producing the same, is made unnecessary.

15.—As of What Date Should the Valuation be Made, and What are "Normal Prices" as of the Date of Valuation?

For practical use, the fair value of a property which must be used is that as of the date or period of use. Thus, for use in condemnation, it must be the fair value of the property as of the date of condemnation.

For use in the regulation of rates, it is necessary to bear in mind that it is undesirable to make frequent modification of rates, but that, on the contrary, they should be determined so as to be fair, on the

average, over a considerable period of time. This necessitates the drawing of conclusions as to the probable average conditions as to prices, etc., which will exist during such future period. The unit prices most satisfactory to be used for valuation for such purpose are those which, it is considered, will probably be a fair average of the prices over such future period. The only method of estimating probable future conditions is through the study of the past conditions; therefore, the ascertainment of average unit prices year by year over a considerable period of the past is necessary. In determining the average unit price for a given period of the past, actual sales furnish the basis. Inasmuch as these sales vary greatly in quantity, it is necessary that the average used be a weighted average and not merely an arithmetical average.

Normal price as of a given date may be defined as being the market price as of that date, assuming business conditions to be normal and not under the influence of undue optimism or pessimism as to the future.

16.—How can Valuation be Kept up to Date for Rate Regulation Purposes?

It must be borne in mind that valuation is not and cannot be made an exact science; neither is there any practical necessity that it should be so. The true measure of the value of a property, as has already been stated several times, is its profitableness, present and prospective, actual and anticipated. Evidently, prospective and anticipated profitableness in themselves can be estimated only approximately, and yet, in nearly all commercial transactions, it is the future prospect rather than the present fact which determines the investor's conclusions as to present value.

Having determined, with such reasonable accuracy as may be, the present value of a piece of property (future prospects being one of the vital considerations), the most important factors which, in the future, will bring about a modification of such estimated value are the appreciation and depreciation in the value of land owned or used, like fluctuation in the prices of labor and material such as have already entered in the construction of the property, the invention of improved methods of construction; additions and betterments necessary to the growth of the business will add quantities to those existing as of the date of valua-

tion; and property abandoned on account of obsolescence, etc., will reduce the valuation quantities. All these changes over a reasonable period of years, together with their effect on the future profitableness of the property, are considered in arriving at the original valuation; further, it is greatly to the interest of the public to avoid frequent fluctuations in commodity prices (freight and passenger rates, etc.). Presumably, therefore, the fair rates established at the time of the valuation (which rates are based, not on the conditions as of the instant of valuation only, but on prospective conditions as well) will be fair for a considerable period of time thereafter. Fluctuations due to additions and betterments and to abandoned property can be taken care of with considerable accuracy by the application of ordinary accounting methods. Variation in the fair value due to fluctuation in unit prices of labor and material can probably only be dealt with either by a new valuation from time to time, or by the keeping of a suitable index number such as that maintained by Bradstreet's, the *London Economist,* and others, but adopting a base arranged to represent the more important kinds of labor and material used in railway construction in their proper proportions, and using the fluctuations of this index for the purpose, from time to time, of applying percentage corrections to the original fair value. Fluctuations in land value could probably only be allowed for through the occasional making of re-appraisals of selected properties and through the application of a percentage correction to all the land values.

A percentage correction applied in such manner to the original valuation, although crude, would still probably greatly extend the period of serviceability of the original valuation.

17.—Comparison of the Cost-of-Reproduction Method with the Prospective Competitor Method of Valuation.

1.—Land Values.—The competitor method assumes that, in the construction of its property, the competitor will be obliged to purchase land having the same present ordinary values and being subdivided in the same manner as similar lands adjoining the property under valuation as of the date of valuation. This avoids the absurdity, pointed out by Justice Hughes in the Minnesota Rate Case, of assuming that the railroad producing much of the value of the land is non-existent, but that the land retains its full value. Presumably, it might be

claimed that the competitor, in entering a town, would select a location for its line and for its terminals which would cost less per acre than the lands adjoining the property under valuation. The answer is that it is fair to presume that the original railroad located its line in such manner as to make the cost of land plus the cost of grading and other improvements a minimum, considering the value of the location with reference to convenience of access for traffic. The adoption of a different location would mean different grading quantities and also the estimating in terms of earning power of the difference of attractiveness of the two locations. This would involve such excessive complications as to make the problem practically unsolvable. The fair presumption is that the original line secured the best available location, cost considered, and that any other location would cost more or would be worth at least proportionally less. In practical operation and in results obtained, the two methods are identical, as to land. The competitor method is logical whereas the other is not.

2.—Present or Past Conditions.—By the competitor method, all questions as to whether present or past conditions apply in making the estimate are solved without difficulty. The reproduction theory affords no positive clue as to whether present or past conditions should be considered in individual cases, and there is much present controversy over this point.

3.—Construction Period.—The reproduction theory involves the reproduction of the property, as it is to-day, in one operation; thus, a four-track railroad would be reproduced as such absolutely regardless of the fact that no railroad, either the original occupant of the territory or a later competitor, ever is built in such a manner. The competitor theory calls for a gradual construction and development of the competitor at a rate dependent on rate of growth of traffic in the community and is, therefore, consistent with the invariable facts of such industrial development.

4.—Going Concern Value, and Cost of Development of Earning Power.—The reproduction theory admittedly carries the process of estimating value only to the point where the property has prepared to become a going concern but has not taken that step. This leaves an element of value called by the Courts "going concern value" to be ascertained by some succeeding process. No process departing greatly from clairvoyance has yet been devised. The competitor theory pro-

vides for the estimating of the cost of the development of the traffic on a basis readily applied in practice and governed by the application of simple principles to easily ascertainable facts.

III. A Study of the Virginian Railway.

In 1902, the construction of what is now the Virginian Railway was actively commenced by the late Mr. H. H. Rogers, the primary purpose being the economical transport of bituminous coal in great volume to the seaboard. The work was pushed as rapidly as financial conditions would permit. Covering the number of years that it did, the rapid completion of course was interfered with by various periods of business depression. The property is one of the few railroads in the United States which has been conceived and developed as an independent enterprise, most of the present railroad systems having been developed as separate entities and gradually combined. The statistics of this railroad, consequently, are of unusual interest for the purpose of illuminating the various problems connected with the ascertaining of the value of railroad properties.

Operation was commenced on the Virginian Railway in 1910, eight years after the commencement of construction. Thereafter, expenditures for construction (usually termed additions and betterments) were, in the main, for providing the additional facilities required to handle the rapidly developing business. The records of the company, partly owing to the fact that practically all the financing was done by Mr. Rogers himself, do not disclose the amount of capital invested in the enterprise as interest. It will be assumed, therefore, that sufficient capital for the ensuing 12 months was secured at the beginning of each such period and that 6% compounded annually had to be paid thereon. With this assumption, Table 2 gives the essential financial history of the Virginian Railway from its inception in 1902 to June 30th, 1916, and also shows what this history would have been had the rate level been 8% higher than it actually was.

For purpose of illustration, assume that to-day as compared with the period 1902-16:

(1).—There has been no change in construction methods or in unit prices of labor and material or in land values. Assume, further,

(2).—That the history of the Virginian Railway has been unaffected by the presence of competitors.

(3).—That the construction of the Virginian Railway and its traffic development proceeded at a normal pace.

(4).—That its physical condition was normal, that is, there was no matured deterioration, throughout its history.

(5).—That the rate level throughout the history of the property was fair.

Under such assumptions there would probably be few who would question that, as of the date of valuation, the fair value of such a property is measured by its cost to date—in this case, \$69 522 883—as of June 30th, 1916.

Taking up the various assumptions and assuming that 6% is the fair rate of return on the fair value of such a property, the following considerations suggest themselves:

1.—Six per cent. on \$69 522 883 is \$4 171 373, whereas the net earnings for 1916 are \$3 331 957. Evidently, on that date, the property was not earning a fair return on its cost. If the rate level throughout the history of the property had been 8% higher than it actually was, then the cost to date would have been \$65 996 540; 6% on this amount is \$3 959 792 and the net earnings for 1916 would have been \$3 923 187, indicating that, based on these considerations alone, the rate level was about 8% too low throughout the history of the property and that, for this reason, the property to the end of 1916 has cost \$3 526 343 more than it would have cost if the higher rate level had been in effect. Had the higher rates been in effect, the public, during the period, would have paid \$2 877 237 more for transportation than they did.

Question A.—Should this increased cost equitably fall on the owners of the railroad through the assumption of the lower figure or should it fall on the public through the assumption of the higher figure as being the fair value of the property as of June 30th, 1916, under the above assumptions?

2.—Assume that the earning power of the property had developed more rapidly, so that, in 1914, the net earnings had been equal to the actual net earnings of 1916. This would have required a corresponding acceleration in the additions and betterments, and the cost to date as of June 30th, 1914, would have been \$63 632 623 for a property identical in

every way with the actual property as of June 30th, 1916, which actual property cost $69 522 883 a difference of $5 890 260. On this new basis of development of earning power, the rates were about 5% too low to give a 6% return on the cost to date of the property as of June 30th, 1914, whereas they were 8% too low to give a 6% return on the identical property with the development period two years longer.

Question B.—Should this excess cost be borne by the public through its inclusion in fair value as of a given date, or should it be borne by the owners of the property through its exclusion?

Question C.—If the owners of the property should be penalized for their bad judgment in commencing the enterprise in advance of the normal public need, thereby adding to its cost, should they also be rewarded if they delay the carrying out of the project until the public need becomes abnormally acute, thus reducing the cost of the project? If bad judgment is penalized and good judgment not rewarded, what will become of the industry—collapse, or Government ownership?

Question D.—How shall it be determined whether or not the inception of the enterprise was in advance of the normal public need?

3.—Going back to the first case—that of the actual history of the Virginian Railway—suppose the date of valuation had been taken as of June 30th, 1914, instead of June 30th, 1916. In that case the cost to date of the property would have been $63 149 009; 6% on this amount is $3 788 940, whereas the actual net earnings for that year were only $2 641 048.

If the rate level had been 9% higher than it was, the cost to date would have been $62 884 206; 6% on this amount is $3 773 052 as against net earnings at the new rate level of $3 718 861 indicating that, under such conditions, and not considering the future, the rate level was slightly more than 9% too low as against an 8% deficit if the year 1916 had been adopted as the basis of calculation.

Question E.—In 1910 (the year in which the Virginian Railway was opened for operation), in determining the rate level to be used in the future on this property (on the assumption that it was not subject to competition) should this rate level have been based on the estimate that in 1914 it would give a fair return on the cost to date, or should it have been based on the fair return being reached in 1916, or in some other year? What considerations should determine the year to be selected?

Question F.—The coal traffic of the Virginian Railway is in competition to tide-water with the coal traffic of the Chesapeake and Ohio and of the Norfolk and Western Railways. If it is assumed that the actual rate level (which was 8% too low to give a 6% return on the cost to date of the Virginian Railway, as of June 30th, 1916) was just sufficient to give a 6% return on the cost to date of the Chesapeake and Ohio and of the Norfolk and Western Railways, would this fact have any bearing on the fair value of the Virginian Railway?

Question G.—Since the inception of the Virginian Railway, there has been an increase in unit prices of labor and material used in construction and operation and in the price of land along the railroad right of way. Do these facts have any bearing on the fair value of the Virginian Railway?

Question H.—If it is assumed that, for several years just prior to the date of valuation, the Virginian Railway had either been parsimonious or excessively liberal in the renewal of its rail, ties, and other materials, would this fact (which certainly would affect the operating expenses of the immediately succeeding years) have any bearing on its fair value as of the date of valuation?

It is the study of such considerations as those mentioned in the preceding paragraphs which has led very generally to the conclusion stated elsewhere, that there is no general relation existing between the cost and the fair value of a property. It is evident that, if cost is to be used in the determination of fair value, it must be used only under such special circumstances as permit the relation between cost and value to be known.

The object of the Prospective Competitor Method of valuation is to ascertain the character of these special conditions and the relation which, under such conditions, exists between cost and value.

Applying to the Virginian Railway the Prospective Competitor Method of valuation, still assuming—for the purpose of illustration and because the data are lacking—that the value of the property is unaffected by the presence of competitors and that, since its inception, there has been no change in unit prices of labor and material, in land values, or in engineering methods:

1.—Under the assumption that the original construction proceeded at a normal pace, it is to be assumed of course that the construction of

TABLE 2.—VIRGINIAN RAILWAY ACTUAL ORIGINAL COST TO DATE *vs.* COST IF RATES HAD BEEN 8% HIGHER.

Year ending June 30th.	Year.	Annual construction cost, exclusive of interest.	Annual Gross Operating Earnings, Exclusive of Interest.		Actual annual operating expenses, exclusive of depreciation.	Annual Net Operating Earnings, Exclusive of Interest and Depreciation.		Net Annual Income or Expenditure—All Sources, Except Interest and Depreciation.		Original Cost to Date.	
			Actual.	With 8% rate increase.		Actual.	With 8% rate increase.	Actual.	With 8% rate increase.	Actual.	With 8% rate increase.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1902	1	$4 885	....	....	....	....	....	$4 885	$4 885	$5 178	$5 178
1903	2	124 991	....	....	....	....	....	124 991	124 991	137 979	137 979
1904	3	803 553	....	....	....	....	....	803 553	803 553	998 023	998 023
1905	4	2 002 747	....	....	....	....	....	2 002 747	2 002 747	3 180 816	3 180 816
1906	5	8 068 906	....	....	....	....	....	8 068 906	8 068 906	11 924 705	11 924 705
1907	6	13 914 302	....	....	....	....	....	13 914 302	13 914 302	27 389 347	27 389 347
1908	7	5 713 959	....	....	....	....	....	5 713 959	5 713 959	35 089 504	35 089 504
1909	8	6 487 348	....	....	....	....	....	6 487 348	6 487 348	44 071 463	44 071 463
1910	9	1 857 966	$2 063 190	$2 228 215	$1 858 980	$204 210	$369 265	1 653 756	1 488 701	48 468 732	48 293 773
1911	10	5 085 982	3 671 224	3 964 621	2 831 760	839 464	1 132 861	4 246 518	3 953 121	55 878 165	55 381 707
1912	11	1 261 087	4 837 598	5 224 605	3 574 473	1 263 125	1 650 132	Cr. 2 038	Cr. 389 045	59 228 694	58 292 221
1913	12	2 341 028	5 842 584	6 309 990	3 460 099	2 382 485	2 849 891	" 41 457	508 863	62 738 471	61 250 359
1914	13	1 472 432	6 340 079	6 847 285	3 699 031	2 641 048	3 148 254	" 1 168 616	1 675 822	65 264 046	63 149 009
1915	14	1 254 047	5 820 406	6 286 038	3 655 936	2 164 470	2 630 102	" 910 423	1 376 055	68 214 840	65 479 331
1916	15	704 743	7 390 382	7 981 612	4 058 425	3 331 957	3 923 187	" 2 627 214	3 218 444	69 522 883	65 996 540
Totals...	...	$51 097 976	$35 965 463	$38 842 396	$23 138 704	$12 826 759	$15 703 692	$38 271 217	$35 394 284	....	....

the competitor to the beginning of operation will duplicate the historic construction to the same period.

2.—It will be assumed that the business handled by the competitor during the second year of its operation equals one-half that of the Virginian Railway as of the date of valuation. This provides one year of minor operation during which the roadbed is solidifying sufficiently for the normal handling of traffic.

3.—For the reason that traffic in the United States doubles in about 16 years, the total length of the development period for the competitor is taken as 17 years. At the end of this period, the physical property and the density of traffic are assumed to be identical with those of the Virginian Railway, as of the date of valuation.

4.—Through experiment, it is found that a 13% rate increase over that actually in effect during the history of the Virginian Railway is necessary during the period of development of the competitor's business, in order that, at the end of the development period, the competitor shall be earning 6% on its original cost to date. A comparison of the essential data of the Virginian Railway with that assumed for the competitor is shown in Table 3. Table 4 is a comparison of the actual financial history of the Virginian Railway with that history as it would have been if the rates had been 8% higher, and also with the financial history of the competitor with a 13% rate increase.

An examination of Table 4 indicates that the Virginian Railway was not earning 6% on its cost to date to the date of valuation, but that an 8% rate increase would have accomplished this. The effect of this 8% rate increase is to reduce the original cost to date from the actual \$69 522 883 to \$65 996 540. This last amount compares with the original cost to date of \$70 882 787 for the competitor (with its 13% rate increase). This difference of about \$5 000 000 represents the value accruing to the property because of the abnormally good judgment used in selecting the Virginian Railway for investment. This enterprise was located so that its rate of growth of business caused it to double in 6 years, whereas the normal rate of growth of railroad business in the United States requires about 16 years.

None of the figures used in the preceding study of the railroad included any amount for depreciation, although it is probable that about \$5 000 000 of accrued deterioration (loss of useful life of the simple parts of the property) existed as of the date of valuation. If it is to be

TABLE 3.—ESSENTIAL DATA, VIRGINIAN RAILWAY HISTORY *vs.* COMPETITOR ASSUMPTIONS.

Year of life of enterprise.	ANNUAL CONSTRUCTION COST, EXCLUSIVE OF INTEREST.		ANNUAL GROSS OPERATING EARNINGS, EXCLUSIVE OF INTEREST		ANNUAL OPERATING EXPENSES, EXCLUSIVE OF INTEREST.	
	Actual.	Programme for competitor.	Actual.	Programme for competitor (13% rate increase).	Actual.	Programme for competitor.
1	$ 4 885	$ 4 885	....	....	....	....
2	124 991	124 991	....	....	....	....
3	803 553	803 553	....	....	....	....
4	2 002 747	2 002 747	....	....	....	....
5	8 068 906	8 068 906	....	....	....	....
6	13 914 302	13 914 302	....	....	....	....
7	5 713 959	5 713 959	....	....	....	....
8	6 487 348	6 487 348	....	....	....	....
9– 1	1 857 966	1 000 000	$ 2 063 190	$ 2 260 000	$ 1 858 980	$ 1 800 000
10– 2	5 085 982	1 000 000	3 671 224	4 181 000	2 831 760	2 800 000
11– 3	1 261 087	750 000	4 837 598	4 463 500	3 574 473	2 900 000
12– 4	2 341 028	750 000	5 842 584	4 746 000	3 460 099	3 000 000
13– 5	1 472 432	750 000	6 340 079	5 028 500	3 699 031	3 100 000
14– 6	1 254 047	750 000	5 820 406	5 311 000	3 655 936	3 180 000
15– 7	704 743	750 000	7 390 382	5 593 500	4 058 425	3 265 000
16– 8	....	750 000	....	5 876 000	....	3 340 000
17– 9	....	750 000	....	6 158 500	....	3 420 000
18–10	....	750 000	....	6 441 000	....	3 500 000
19–11	....	750 000	....	6 723 500	....	3 550 000
20–12	....	750 000	....	7 006 000	....	3 600 000
21–13	....	750 000	....	7 288 500	....	3 680 000
22–14	....	750 000	....	7 571 000	....	3 760 000
23–15	....	750 000	....	7 797 000	....	3 840 000
24–16	....	750 000	....	8 023 000	....	3 900 000
25–17	....	750 000	....	8 249 000	....	4 000 000
26–18	....	727 285	....	8 351 131	....	4 058 425
......	$51 097 976	$51 097 976	$35 965 463	$111 068 131	$23 138 704	$60 693 425

TABLE 4.

Item.	ORIGINAL COST TO DATE, DEVELOPMENT PERIOD 7 YEARS (1910–1916 INCLUSIVE).		Original cost to date of competitor, 17-year development period, 13% rate increase.
	Actual.	With 8% rate increase.	
Construction	$51 097 976	$51 097 976	$51 097 976
Less net from operation	12 826 759	15 703 692	50 474 706
Difference	$38 271 217	$35 394 284	$623 270
Interest	31 251 666	30 602 256	70 259 517
Original cost to date	$69 522 883	$65 996 540	$70 882 787
6% interest on cost	4 171 373	3 959 792	4 252 967
Net earnings last year	3 331 957	3 923 187	4 292 707

assumed that this amount should have been covered by adding a depreciation charge to the maintenance expense and an actual cash reserve established, then it is evident that the original cost to date would have been increased by this $5 000 000. Inasmuch as no such cash reserve has been established, the amount of this reserve would have to be deducted from the original cost to date, in arriving at the value of the property as of the date of valuation. The net result is exactly the same as if depreciation had been entirely ignored—as has been done in the preceding computations. There is nothing in the history of the Virginian Railway to indicate that its physical condition as of the date of valuation was such that maintenance expense in the immediate future would be either abnormally high or abnormally low. Consequently, in so far as depreciation is concerned, there is no need for considering prospective profitableness in connection with the determination of fair value.

Summary.

The Prospective Competitor Method of valuation of property subject to competition is dependent for its successful use on the proper selection of two items, for neither of which the method provides a determination which, in its last analysis, does not depend on the judgment of the user. These two items are: (1) the earning power which the competitor is assumed to have at the commencement of normal operation (say, the second year of operation in the case of a railroad); and (2) the rate of increase of earning power.

Inasmuch as the public does not underwrite the cost of abnormal errors of judgment, among which may be classed the inception of an enterprise where there is not yet a normal public demand for the product, and inasmuch as, consequently, the owner of the property is entitled to reward where exceptionally good judgment has been used, it is evident that these two items must be selected so that they represent normal or average conditions rather than those actually confronting the property under valuation.

With reference to the rate of increase of earning power, the problem is comparatively simple, inasmuch as the average rate of growth of earning power of a given industry in a competitive district is readily ascertainable.

There are several points of view from which the consideration of the earning power to be assumed for the first normal year of operation can

be considered. First, we may consider past history. What was the earning power of the first year of actual enterprises of the character under consideration? The objection to using these data is that the earning power awaiting one enterprise might be satisfactory and yet might be entirely unsatisfactory for a different enterprise requiring a greater initial outlay.

A second point of view is that which considers the normal character of capitalization of enterprises. The early expenditures for construction, etc., must be borne by the owners. After construction has proceeded so far that there is a property having a considerable tangible value, then it is possible for the owner to seek financial assistance through mortgaging his property; especially is this true if a definite earning power has been developed. If, therefore, the initial earning power of the competitor is sufficient to pay operating expenses plus interest on one-half the cost to that date, a definite basis will be established for securing additional capital through a bond issue equal to one-half the cost to such date.

To illustrate: The original cost to the end of the second year of operation of the Virginian Railway's "competitor" was about $56 000 000. Interest at 6% on one-half this sum is $1 680 000. Operating expenses for the second year are estimated to be $2 800 000, the sum of the two items being $4 480 000 as against the $3 671 224 gross earnings actually earned by the Virginian Railway during its second year of operation (at rates apparently much too low).

The history of five other properties shows a second-year gross of from $3 300 to $9 600 per mile of road, that of the Virginian Railway being about $4 600 per mile.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

REPORT ON CAUSE AND CORRECTION OF FOUNDATION TROUBLES OF BOX FACTORY AT NATCHEZ, MISSISSIPPI*

By C. E. Smith,† M. Am. Soc. C. E.

Synopsis.

During 1917 a large box factory was built on a bench of land adjoining the east bank of the Mississippi River, at Natchez, Miss., 75 ft. below the top of a bluff and 150 ft. above the river. The owner was not represented on the work by an engineer or building inspector. The work was carried out by an "Engineering Contractor" on a cost-plus-fee contract. Following the completion of the plant, settlement occurred in the foundations under practically all the buildings and machinery, and it appeared that the entire building site would slip down the hill.

Various causes for the settlement were suggested, such as erosion of the Mississippi River bed under water, settlement of the ground due to fine under-soil carried out through springs by the ground-water, slipping of pervious strata above on the impervious stratum below, etc. Investigation disclosed that neither the erosion of the Mississippi River nor the action of escaping ground-water caused the trouble, which was found to be due to softening of the top 20 ft. of soil by water that could not escape through impervious blue clay under it.

* This paper will not be presented for discussion at any meeting of the Society, but written communications on the subject are invited for subsequent publication in *Proceedings*, and with the paper in *Transactions*.

† St. Louis, Mo.

The trouble was corrected by excavating trenches through the top soil to the blue clay, installing porous tile and wood box drains and back-filling the trenches to the surface with cinders and gravel containing a large percentage of sand. Immediately following the completion of the drainage system all ground movements stopped, the defective foundations were corrected, additional boilers, engines, and other facilities were installed, and no further foundation trouble has occurred. A total expenditure of about $20 000 for drains stabilized the soil and made it possible to continue the operation of the factory.

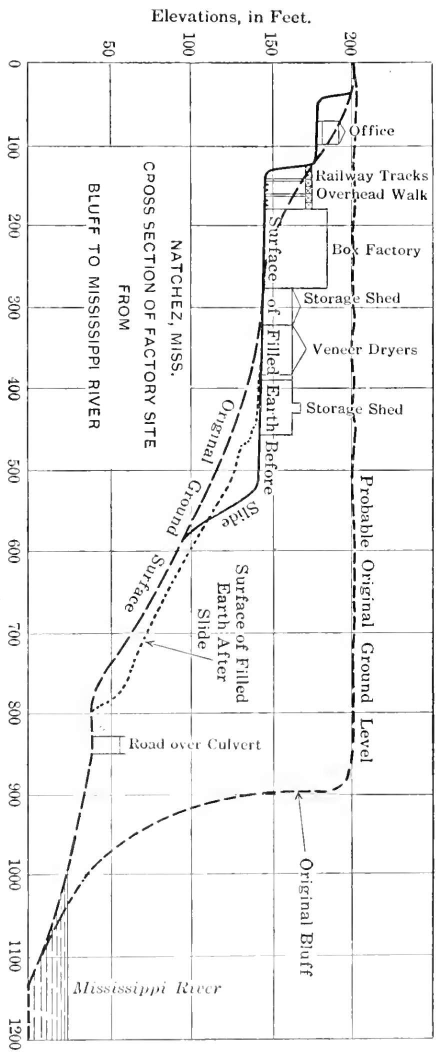
More than $25 000 had been spent in a futile effort to stop the movement by driving timber piles into the moving ground and the plant was operated at very low efficiency on account of frequent shut-downs, resulting in large operating deficits each month. Immediately following the stabilization of the foundations the plant overcame all deficits and showed a profit.

During 1917 a large factory for the manufacture of wood boxes, tubs, and veneer was constructed under contract on the east bank of the Mississippi River at Natchez, Miss. The general plans were prepared in the office of the owners at Chicago, Ill., who were represented on the construction work by a bookkeeper; the future plant manager visited the work occasionally. The owners did not have an engineer or building inspector on the work, as it was thought that the "Engineering Contractor" would automatically provide the engineering and inspection. Later developments indicated that special engineering knowledge and advice during the construction period were conspicuously absent, and nearly resulted in the wrecking of the plant.

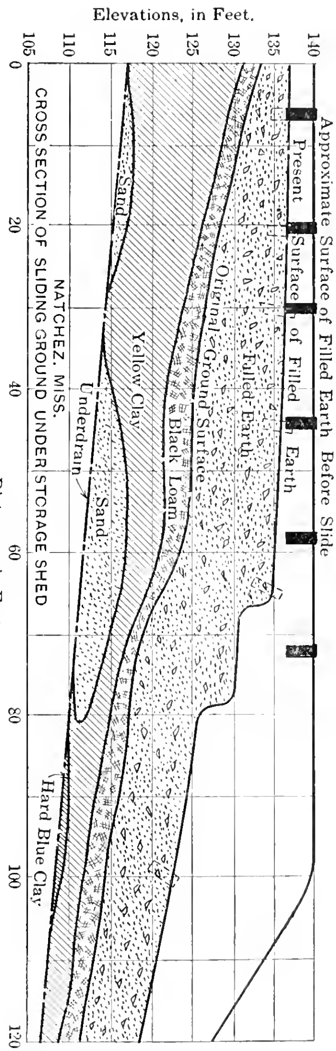
Ground Conditions and Movements.

At the site of the factory the Mississippi River has a vertical rise and fall of about 50 ft. The bank slopes upward about 1 in 5 for 750 ft. back from the high-water line to the highest ground 150 ft. above. A cross-section of the bank between the river and the top of the bluff at the site of the plant is shown in Fig. 1.

The surface of the sloping bank consists of a thin layer of black loam, under which is yellow clay of indefinite depth. In this clay appear, at several depths, and in irregular thicknesses and extent,



Distances, in Feet.
FIG. 1.



Distances, in Feet.
FIG. 2.

various strata of coarse sharp sand, fine quicksand, mixtures of this fine sand and clay, and sloping layers of blue clay. The mixture of fine sand and clay is very firm and hard when dry, but when saturated with water it becomes a typical quicksand.

For many years, beyond the memory of the oldest settler, this typical Natchez river bank has been sliding or flowing toward the river, causing continual disturbance and subsidence of the ground surface on the slope. The movement of the ground was a miniature reproduction of glacial action. A typical cross-section at a point where the greatest movement took place is shown in Fig. 2.

Residents over 80 years old remember being told of the time when the slope was higher and level and occupied by buildings. It appears that the high ground originally extended out to a bluff on the river bank and that the present slope is the result of the sliding to which reference has been made.

At extreme low water, or zero gauge of the Mississippi River, a porous stratum of cemented gravel and sand with a small mixture of iron ore, locally referred to as "ironstone", outcrops along the entire Natchez water-front and gives forth an abundant flow of clear cool water through numerous springs.

This emergence of the underground water 200 ft. below the high ground above has been commonly held as the reason for the sliding and settling of the sloping bank. A careful examination of the porous stratum and of the springs, together with other conditions and information, convinced the writer that the sliding and settling were not due to this cause. The water emerging from the porous strata comes out perfectly clear and does not carry any sediment. If, in fact, fine sediment were being carried out from deep levels by this underground water, undoubtedly caves would be formed, which, in the fine, easily broken-down soil that overlays the cemented gravel, would ultimately result in chimneys and sink-holes. There are no such chimneys and sink-holes at Natchez.

Bank Erosion by Mississippi River.

Another theory which was advanced to account for the sliding ground is that the erosion of the river bank below low-water level caused the bank to subside and gradually flow toward the river. This theory was strengthened by the fact that within the memory of present

residents of Natchez the river has made extensive inroads on the lower portion of the city. The present high ground on which the city is located was formerly separated from the river by an area of comparatively low and level ground, four or five city blocks in width, fully occupied by buildings, known as "Natchez-under-the-hill".

Approaching Natchez from up stream, the river makes a long sweep or bend and takes a direction nearly at right angles to the bank, then turns in another bend to follow the direction of the high ground. The low ground of "Natchez-under-the-hill", having been located in the bight of the bend, was eroded until it nearly all disappeared, barely space enough remaining for one street on the side-hill between the water and the bluff. Further erosion of the bank was prevented by mattress and revetment work placed by the United States Government. The United States Engineer Corps took numerous and frequent soundings along the front, a study of which indicates that since the revetment was placed, no further erosion has taken place. The bank down stream from the revetment, opposite the site of the factory, has not eroded to any appreciable extent, and it does not appear that the sliding and subsidence of the sloping bank above high water was due to the erosion of the banks by the river. The river is quite deep, the bed being 60 ft. or more below low water.

According to Mark Twain's reference to "Natchez-under-the-hill", its disappearance might have been a well merited fate. In his "Life on the Mississippi", about 1880, he refers to it as follows:

"Famous Natchez-under-the-hill has not changed notably in twenty years; in outward aspect—judging by the descriptions of the ancient procession of foreign tourists—it has not changed in sixty; for it is still small, straggling and shabby. It had a desperate reputation, morally—in the old keel-boating and early steamboating times—plenty of drinking, carousing, fisticuffing, and killing there, among the riff-raff of the river, in those days. But Natchez-on-top-of-the-hill is attractive, has always been attractive."

Plant Site and Buildings.

A site for the factory was prepared by leveling the slope about 60 ft. below the top to a bench approximately 350 ft. wide, the deepest cut in the bluff amounting to nearly 30 ft. and the highest fill about 25 ft.

The factory buildings, covering about 2 acres, and including the boiler-house with brick stack, engine-house, veneer mill, kiln veneer dryers, storage sheds, box and tub factories, soaking vats, elevated water-tanks, and appurtenant log conveyors and tramways, derricks, and saw-mills, were built on the graded ground. The construction was completed, and operation of the plant commenced early in 1918.

Failure and Movement of Foundations.

Less than a year after the completion of the plant, and during the rainy season, the ground sheared vertically along several lines normal to the slope of the hill-side, with a settlement of from 2 to 15 ft., and slid down the hill-side, carrying large sections of surface earth with growing trees as far as 200 ft.

A typical crack in the ground preceding a slide is shown in Fig. 4. The lower slope of the sliding ground is shown in Fig. 6.

Shortly after operations commenced, the foundation walls under the boiler-house broke, and the river end settled about 1 ft. and moved toward the river 1 ft.; the brick walls fell down, the brick boiler settings of two 300-h. p. boilers were shattered, and the boilers pulled away from the breeching. The 90-ft. brick stack settled and caved slightly, and the water-tank footings showed a slight settlement.

The plant was originally operated by a 550-h. p., Corliss engine and line shaft. The engine foundation settled and threw the engine out of setting. The concrete foundations under the 6-in. jack-shaft settled several feet and slid 5 to 10 ft. entirely outside of the engine-house. The engine-house foundations on the river side settled and slid completely out from under the engine-house. The movement of these footings is indicated in Figs. 7 and 8.

Practically every footing under the storage shed settled and moved out of place. The outside row on the river side settled over 15 ft. and slid out nearly 30 ft. About seventy footings settled and moved. Figs. 3 and 5 show the nature and extent of this settlement and movement.

The settling ground extended back to the foundations of the heavy veneer mill and planers and the kiln veneer dryers; it broke sewer and water lines, caused frequent long shut-downs, made it impossible to get on a production basis, and, for a while, it appeared as if the

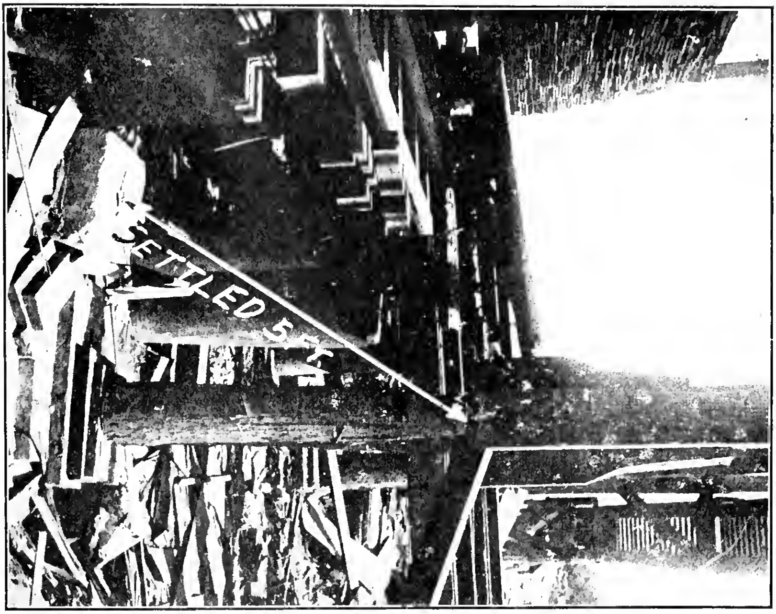


Fig. 3.—Concrete Footings Under West Edge of Storage Shed.

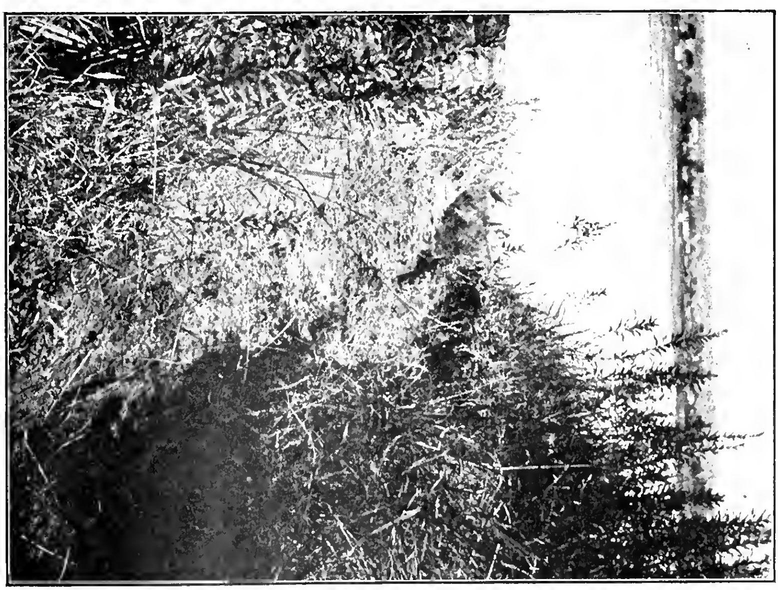


Fig. 4.—Typical Crack in Ground Preceding Slide.

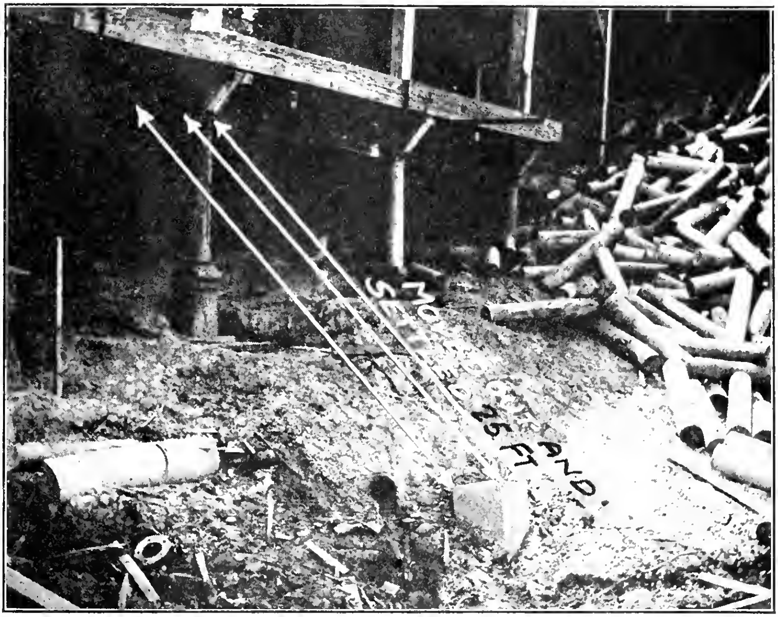


FIG. 5.—CONCRETE FOOTINGS UNDER WEST END OF STORAGE SHED.

FIG. 6.—LOWER SLOPE OF SLIDING GROUND.

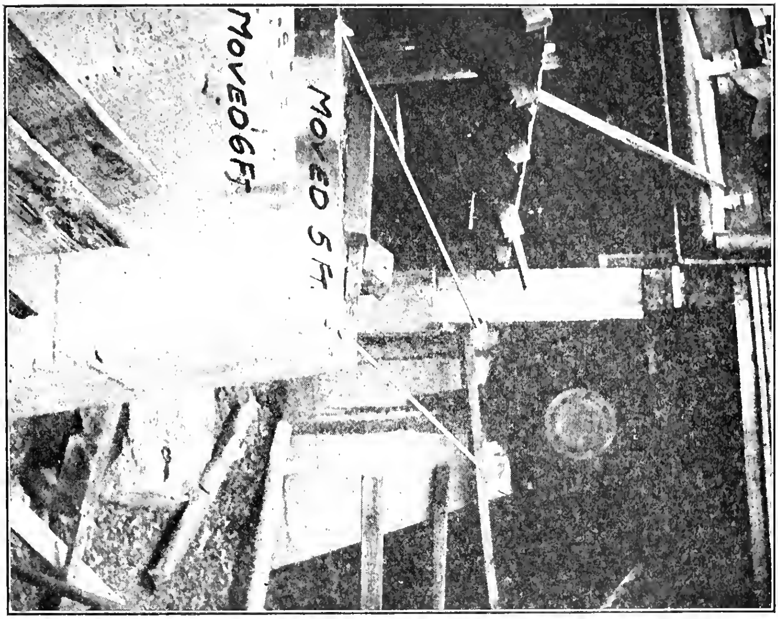


FIG. 7.—CONCRETE FOOTINGS UNDER MAIN LINE SHAFT.

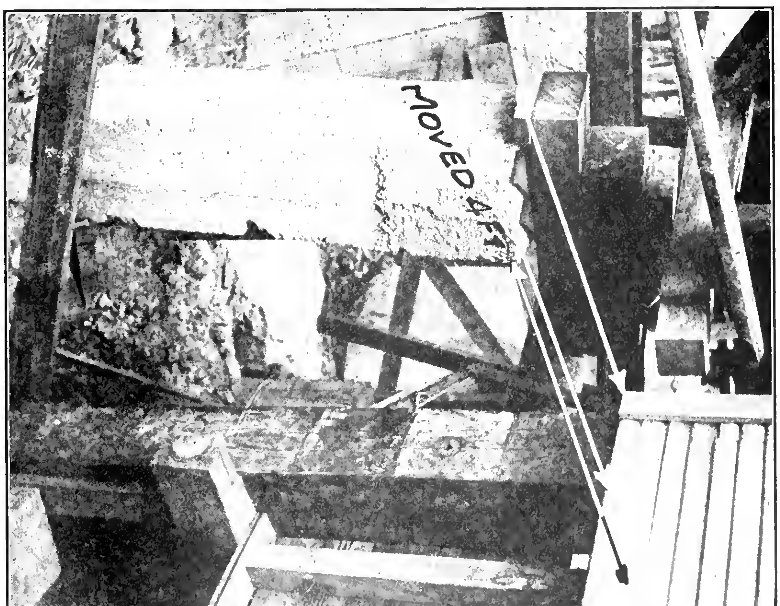


FIG. 8.—CONCRETE FOOTING UNDER CORNER OF ENGINE HOUSE.

enterprise would have to be abandoned, and the plant moved to another site.

Emergency Repairs.

Ineffectual methods were adopted to stop the sliding ground. Timber piles were driven into the ground, but they were carried right along, tipped over, upheaved and literally thrown out of the ground by the movement, as shown in Figs. 9 and 10.

After closing down for sixty days, the factory was continued in intermittent operation with the greatest difficulty by keeping gangs of workmen all over the plant jacking and propping the buildings on the moving ground. A new connection was made between the unaffected portion of the jack-shaft and the re-set Corliss engine. A new engine, with dynamo, was installed and motor drive put on several machines.

Investigation of Trouble.

After this painful experience had continued for about a year, the situation was brought to the writer's attention for the first time early in 1919, when the owner requested that an examination be made, the trouble diagnosed, the remedy prescribed and estimated, and recommendations submitted for further procedure.

After a careful examination, the writer concluded that neither the erosion of the river nor the springs at low-water level had anything to do with the settlement, but that it was due to local conditions, and that the ground movements and slides could be stopped by a system of under-drains. The filled earth was a very loose mixture and contained a quantity of rubbish which prevented it from packing and forming a hard surface such as would permit water to flow off rapidly. On the contrary, the surface was broken by cracks and depressions which collected the water and caused the filled earth to become rapidly saturated to the depth of the original ground surface.

On this less pervious surface the water collected, saturated the loose loam and clay to a slimy mass, 1 or 2 ft. thick, and started to flow down the slope. Farther down the hill-side at the lower end of the fill, the water came to the surface washing with it a mass of soft mud. As this mud oozed out, the earth above settled and this, in turn, became saturated and started to flow. Where the soft earth at the level of the original ground surface did not flow enough to cause a vertical settlement, it formed a slippery layer on which the loose earth above could slide.

Conditions which were bad enough after weeks of torrential rains common in the lower Mississippi Valley, were made worse by surface drains both for storm-water and for water resulting from the operation of the plant and, after the first slight movement of earth, by a number of leaks in under ground water pipes and sewers.

The slide as well as the vertical settlement was further augmented by hundreds of tons of log cores from the mill, which were piled on the hill-sides near the top of the slope. Besides placing a great weight on top of the moving earth, these cores furnished crevices and openings in the ground surface through which the water soaked into the earth instead of running off.

Construction of Under-Drains.

A comprehensive system of porous under-drains, with a combined length of 2 870 ft., was placed under and around the principal buildings of the plant. These drains consisted of tile pipes or perforated wood boxes placed at depths of from 10 to 25 ft. in trenches, which were then back-filled with gravel or cinders. The trenches averaged 30 in. in width, which was as narrow as they could be dug conveniently to the required depth.

Tile pipe of sizes from 6 to 12 in., which could be placed more cheaply than wood box, was used in all lines where the earth was not moving; but at points where movement was taking place it was found that sections of pipe pulled apart too easily, and continuous wood box was used instead. Wherever possible this was kept below the plane of the slide.

This wood box was built of 2 by 12-in. cypress planks, the sides resting on the bottoms so as to make the interior dimensions 8 in. wide by 12 in. high. The sides and top were perforated with 1-in. holes in two rows, at 8-in. intervals in each row. The joints between the side and bottom planks of the box were well caulked with oakum and then covered with narrow lath. These joints were broken so as not to have successive planks in the side to join at the same section at which planks joined in the top and bottom; all were held by 2 by 12-in. scabs, 3 or 4 ft. long, well spiked at both ends so as to keep the box from pulling apart during slight movements of the earth. The lumber used was a low grade of pecky cypress which was found to be quite satisfactory.

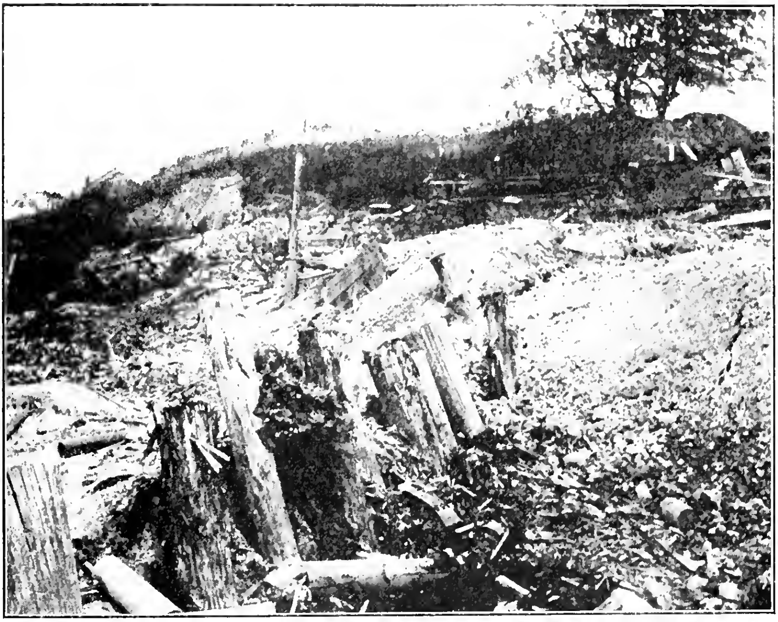


FIG. 9.—TIMBER PILES DRIVEN IN EFFORT TO STOP EARTH MOVEMENT.

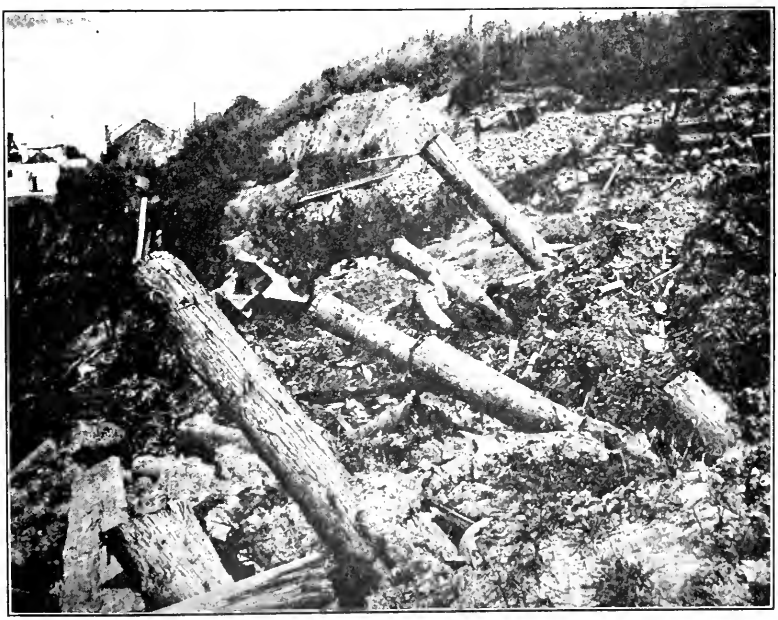


FIG. 10.—TIMBER PILES DRIVEN IN EFFORT TO STOP EARTH MOVEMENT.

From the lower ends of the under-drains the flow was carried down the hill-side in open flumes of wood, of the same cross-section as the box underground. Points at which the drains came to the surface were selected, on steep slopes, so as to have the drain-pipe or box pass through as short lengths as possible of the surface earth, as this was constantly in motion and tended to pull the sections of pipe and box apart. The open flumes were placed on timber bents spaced 10 or 12 ft. apart. The flume was kept from disjointing at each slight displacement of the bents due to movement of the earth. The bents could be put back in place after each movement without injuring the flume.

After the completion of the under-drains the earth near them, especially on the hill-sides, was graded to slope uniformly toward the gravel-filled trenches through which the water passed to the under-drains.

The flow through the several drains was measured daily during their construction, and that through each drain was found to decrease gradually for two or three weeks after its completion, which indicated that the level of the ground-water was being slowly lowered. The total underground seepage after the drains had been in place sufficiently long to have reached their minimum of flow, and after defects in the surface drainage had been corrected, amounted in the driest weather to about 12 000 gal. per day from an area of about 4 acres, 2 acres of which are covered by buildings the drainage from which is otherwise disposed of. This was increased to about 100 000 gal. per day in very wet weather.

Movement of the ground stopped promptly at one point after another as the drains at these respective points were completed, until the work was finished. After completion, not the least movement could be noticed at any time. The earth, which formerly was muddy and soggy from one rain until the next, now dries rapidly after each successive downpour and is perfectly stable. The plant, valued at $800 000, in serious danger of ruin, has been made safe for operation by an expenditure of less than $20 000.

Although several months have elapsed since the completion of the drains, there has been no further trouble. The drains were placed

during the early summer of 1919. In February, 1920, the manager of the factory advised as follows:

"I am very pleased to report that even in the face of the continuous rains all through the summer and up to the present time, even in a heavy rain which we had in January, when it rained about 7 in. in two days, that there was absolutely no movement in any part of the hill where the drains were put in."

Cost of Drainage System.

The cost of the work was as follows:

Excavation per Cubic Yard:	
Handling earth (in addition to actual excavation, this includes an average haul of 250 ft. for all excavated material)	$2.00
Miscellaneous items (this includes bracing the trench, foreman's supervision, trench-jacks, lumber, and rubber boots)	1.35
Total	$3.35
Back-filling per Cubic Yard:	
Labor (this includes handling of gravel from railway cars to the several drains, with an average haul of 250 ft.)	$1.90
Gravel, including freight	2.10
Total	$4.00
Placing Wood Box per Linear Foot:	
Labor (time of carpenters and laborers building the box, and placing it in the trench)	$0.65
Cost of timber	0.20
Total	$0.85
Placing Tile Pipe per Linear Foot:	
Labor (time of foreman and laborers carrying the pipe from stock piles to the drains, and placing it in position)	$0.20
Tile pipes, including freight	0.35
Total	$0.55
Cost per Linear Foot on All Operations	$7.20

The trenches reached a maximum depth of 25 ft., with an average depth of 15 ft. All trenches were braced. In many places the soil ran through the cracks like soft ice cream.

The unit costs for material and labor were as follows:

Cost of Labor per Hour:

Foreman	$0.75
Carpenter	$0.50
Negro laborers (10-hour day)	$0.25 to $0.30

Costs of Material per Cubic Yard:

Gravel ($1.20, freight $0.90)	$2.10
Cinders (loading and switching charges only)	$0.80
Lumber, pecky cypress, per 1 000 ft. b. m.	$30.00

Tile Pipe:

Size, in inches.	Pipe.	Freight.	Total.
6	$0.19	$0.05	$0.24
8	0.27	0.07	0.34
10	0.37	0.09	0.46
12	0.58	0.12	0.70

Other Plant Improvements.

When work on the under-drains had progressed far enough to convince the owners of success, work was started on the reconstruction of the damaged portions of the plant and on several additions. The old foundation of the drag-saw used to cut the rough logs to convenient lengths for the lathes, had to be entirely replaced and the engine operating the saw re-set. The foundation for this engine and saw was 20 by 28 ft., and consisted of twenty-four timber piles with an average penetration of 25 ft., capped with a 24-in. slab of concrete.

A small saw-mill was built adjacent to the drag-saw. The point of the hill on which this was located had not yet been cared for by under-drains and was still moving at the time the mill was built. For this reason, it was decided to place for a foundation a heavy frame of 12 by 12-in. timbers which could be jacked up and leveled after slight movements of the earth until such time as it would be quite stable, when a more stationary foundation could be placed.

In order to join this saw-mill with the veneer mill and the drag-saw with the boiling vats, conveyors and a heavy timber platform 9 ft. high were built to replace an old conveyor and platform which had been completely wrecked by the slide. All these structures were placed on timber piles, with penetration well into the original solid ground beneath the slide. The piles under each conveyor were placed at 8-ft. centers in each of two rows 5 ft. apart. Under the platform they were at 6-ft. centers in both directions.

All water pipes and sewers were seriously damaged by the earth movement and required extensive repairs. The fire protection sprinkling system was entirely removed from underground and put overhead.

The additions to the plant consisted of two new boiling vats, three new boilers with a combined capacity of 1 100 h. p., a new self-supporting steel stack, 8 ft. in diameter and 135 ft. high, and a new engine and 500-kw. generator. The boiling vats were each 9 ft. by 40 ft. over all, with a depth inside of 10 ft. The walls tapered from 9 in. thick at the top to 18 in. thick at the bottom, and each rested on a single row of timber piles driven at 3-ft. centers. The piles were capped with a 2-ft. floor slab.

The boilers, the stack, and the new engine and generator were not placed on piles, as the earth at these points was considered to be stable enough after the completion of under-drains in this vicinity to use the customary spread foundations of concrete.

Supervision of the Work.

The trouble was investigated and the remedy prescribed by the writer; the construction work of putting in the drains and the foundation work for correcting the defects and for the additional mechanical and electrical equipment was supervised by Assistant Engineers M. H. Doyne, Jun. Am. Soc. C. E., and Mr. G. C. Hetlage.

No contract was let. The materials were purchased by the Box Company, the labor was carried directly on its pay-roll, and worked under the Assistant Engineers. The additional mechanical and electrical equipment was specified by D. MacKenzie, Consulting Engineer, of Chicago, Ill., and installed by Mr. Robert Warmack under the supervision of Mr. MacKenzie.

The investigation, installation of the drainage system, correction of defects, and additions to the plant were carried out under the

general supervision of J. W. Drissen, General Manager of the Box Company.

Conclusion.

The employment of competent engineering assistance during the construction period would have avoided all the later troubles and expense. The employment of competent engineering service immediately when trouble first developed in the foundations would have saved large sums expended in experimenting and would have avoided the greater portion of the operating deficits. The plant could have been put on a paying basis much sooner with a great saving to the owners.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

ON A NEW PRINCIPLE IN THE THEORY OF STRUCTURES

Discussion*

By George F. Swain, Past-President, Am. Soc. C. E.†

George F. Swain,‡ Past-President, Am. Soc. C. E. (by letter).§— Discussion on this paper would naturally be directed to (1) criticism or commendation of the principle or the writer's presentation of it; or (2), whether, as the writer supposed when he presented it, it was novel. Mr. Swain

There has been little criticism, except in two instances, of the principle itself, or of its presentation, and the writer here expresses his thanks for the commendatory remarks which have been made by many who have discussed it. As to the principle itself, it is simple and fundamental, and stands alongside the principle of deflection first given by Maxwell, and first published in this country by the writer, as a wholly similar method of finding rotation. There is no question as to its correctness, though one contributor does not admit it.

It should be stated at once that the writer did not claim anywhere that the problems which could be solved by the aid of the principle could not be solved otherwise, in some cases as easily as by its aid, and in some cases more easily than by it. The object was merely to present it as a fundamental principle in the theory of structures which he believed had escaped recognition by American engineers even if, as he suggested, it had been published before, although he was not aware and still does not believe that it had, in its general form. The discussion affords good evidence that it had not been recognized or appreciated, even if it had been known.

* Discussion of the paper by George F. Swain, Past-President, Am. Soc. C. E., continued from February, 1920, *Proceedings*.

† Author's closure.

‡ Cambridge, Mass.

§ Received by the Secretary, March 4th, 1920.

Mr. Swain. Since the paper was published, the writer has found—partly from the references quoted in the discussions, and partly in other ways—that, as he had surmised, the principle had been known, in Europe, but only as applied to beams, and not as applied to trusses or combinations. He does not believe, however, that the principle had been at all recognized or used in America, either for beams or trusses, although it is referred to in one American book, but not explained or illustrated even there. The book referred to is "Bridge Engineering", Vol. I, by J. A. L. Waddell, M. Am. Soc. C. E., where, on page 231, after referring to the formula for the deflection of a beam,

$$\delta = \int_0^l \frac{M\, m\, d\, x}{E\, I},$$

it is stated:

"If it should be desired to find the amount of rotation of a given point of a beam, a couple with a moment of unity can be placed at the said point, and Equation (5) applied by changing δ to α (the angle in radians through which the point turns), the values of m being those produced by the unit couple".

The writer has not found in this book, or any other, any reference to its application to trusses.

Bearing in mind that the writer's paper showed a method of finding the angular rotation of the axis of a piece at any point, due to given loads, whether the piece is a straight or curved beam, or a truss member, or both, it may be well to consider some of the references given by those who claim that the principle is not new.

Professor Parcel states* that the principle is not new, but he says it is little understood. He gives several references. The writer does not find in Molitor's work, on page 18 or pages 28-29, or elsewhere, any statement of the principle. Hartmann, pages 9-11, finds rotation only for solid beams, and on pages 24-33 there are only illustrations for solid beams, with no hint of its being a general principle. Mehrtens, at the pages cited, or elsewhere, gives no statement of the principle at all, but treats an entirely different problem, namely, that of finding the angular rotation of a line passing through any two joints of a frame. If a line, L, is drawn through any two joints of a frame, whose distance apart is m, and if it be desired to find the angular rotation of this line under given loads, this may easily be done by the use of deflections. If a unit load is applied at one of the joints, perpendicular to L, and if this load causes stresses, t, in the members, the deflection of the point in the direction of the unit load due to the actual (not unit) loads will be, by the deflection formula,

$$\sum \frac{t\, s\, l}{E\, A}.$$

* *Proceedings*, Am. Soc. C. E., May, 1919, p. 322.

If a unit load be applied at the other joint perpendicular to L, but in the other sense, causing stresses, t', the deflection of this point under the actual loads will be Mr. Swain.

$$\sum \frac{t' \, s \, l}{E \, A}.$$

The sum of these two quantities divided by m, will be the angular rotation of the line; but this will be the same as

$$\sum \frac{t'' \, s \, l}{E \, A},$$

in which t'' is the stress due to a load $\frac{1}{m}$ at each joint, or a unit couple, with one force at each joint. This is easy, and follows, from the deflection formula, but it is not the writer's principle at all.

If Professor Parcel thinks Mehrtens has given the writer's principle, he has failed to grasp that principle. Müller-Breslau is referred to by Professor Parcel. The writer has only the 1907 edition of his "Graphische Statik", but in it finds no statement of his principle. On pages 14-17 the rotation of a line through any two joints, just referred to, is what is found; and on pages 52-57 are historical notes, containing no statement of the principle. Müller-Breslau is also referred to by Professor Church, who cites Equation (54a) on page 133. This equation, however, refers only to solid beams, straight or curved, and is in a paragraph of Abschnitt II, which bears the title "Biegungsfestigkeit gerader und einfach gekrummter Stäbe". His Equation (54a) is obtained from Equations (37) and (38), which, as the figures show, apply to solid beams, not trusses. Also, his Equation (54a) is

$$t_m = \int \frac{N \, n \, d \, x}{E \, I}, \text{ etc.},$$

which clearly shows that it applies to a beam. The writer's equation contains $\Sigma \int$, which is very different.

The writer has found no evidence that Müller-Breslau, or any other European writer, had perceived the principle, except as applied to beams, or, if they had, that they have stated it. Of course, it is easy to see, now that the writer has pointed it out, that the principle is implicitly contained in the work equation, but many things are hidden until they are made clear.

Professor Turneaure states* that the principle is not new to him. This is not surprising, since it is so simple and obvious; but if Professor Turneaure had perceived it, he evidently did not think it important enough to mention, and the writer cannot in the least agree with

* *Proceedings*, Am. Soc. C. E., May, 1919, p. 331.

Mr. Swain. his statement that it is "quite fully set forth" in his book. Indeed, the writer does not believe that anybody, reading the paragraph in Professor Turneaure's excellent book to which reference is made, would get even an inkling of the principle. Let any reader test this. In the first place, the paragraph he quotes deals with stresses in redundant members, and in this case the question of angular rotation is not involved. The quoted paragraph refers to structures which include "members acting as beams". This must mean cases in which the members are acted upon by transverse loads. It cannot refer to secondary stresses, for these are treated in a later chapter which begins with the statement, "It has been assumed heretofore * * * that all members of a truss are free to turn at the joints." What, then, is the meaning of Professor Turneaure's reference to "a bending moment of unity in the redundant member"? At what point in the redundant member? Presumably at the point where the rotation is to be determined. Professor Turneaure, however, nowhere gives any formula for finding rotation analogous to that for finding deflection. The writer's principle deals with a moment unity at the point where the rotation is to be determined, and shows how to find that rotation, and Professor Turneaure nowhere does this. The writer is free to confess that he does not clearly understand Professor Turneaure's quoted paragraph, but he is sure that it does not contain, or even suggest, his principle. Again, the writer has not found anywhere in Professor Turneaure's volumes any statement or illustration of the principle, even for beams.

Replying to Mr. Godfrey,* the writer's object was to present a scientific principle, and to illustrate its application. Mr. Godfrey thinks that "not one engineer in fifty doing practical designing could follow this paper". That, if true, does not speak very well for engineers, and would suffice to explain the low estimation in which many are held. He also thinks "there is no reason on earth why it [the method] should be applied in a practical design." Well, there was a time, not so long ago, when few engineers "doing practical designing" thought that pins in a bridge should be computed at all, or that the eccentricity of connections was of any importance, and similarly for many other things.

Mr. Godfrey must certainly have perceived that where members or frames are rigidly connected, it is necessary to compute or find an expression for the angular rotation at the points of connection. Sometimes a truss is connected to a beam, sometimes pieces in flexure are connected to other pieces in flexure; and if the engineer is to be something more than a "rule-of-thumb" man, able to solve new problems intelligently, he should have at command the scientific principles which will lead to a solution. The principle given by the writer will be found

* *Proceedings*, Am. Soc. C. E., May, 1919, p. 311.

useful by any structural engineer who has the perception and ability to use it, and those who have not will continue to use "rule-of-thumb" methods, and will either make their structures too light, or waste their clients' money. The principle explained has simplicity for its chief merit, being as easily applied as the usual deflection formula, which few engineers "doing practical designing" knew anything about thirty years ago. Mr. Swain.

The writer quite agrees with Mr. Godfrey as to the desirability of simplifying construction and also mathematical processes, and thinks he has done the latter in his paper, as witness his demonstration of the Theorem of Three Moments. It seems therefore rather ridiculous to find Mr. Godfrey implying that the writer's paper tended to complicate mathematical processes. The writer also entirely agrees with Mr. Godfrey as to the necessity of common sense in engineering, and the importance of discriminating between important and trivial theoretical matters. He has preached and practiced this doctrine for more than thirty years; but common sense is not guesswork, and one cannot distinguish between important and trivial theoretical matters unless he understands theory. Certainly a man who could not follow through this paper could not so discriminate, and if engineers "doing practical designing" would give more study to simple fundamental principles, of which the paper illustrates one, there would be fewer of the "flimsy and wobbly buildings" that Mr. Godfrey refers to. There are undoubtedly many crimes committed in the name of theory, yet probably not so many as in the name of common sense. The important things are balance, perception, experience, judgment, and a knowledge of fundamental principles.

Professor Church's discussion,* like everything he writes, is illuminating, and the writer thanks him for his contribution. The difference between the writer's Equation (4) and Müller-Breslau's Equation (54*a*) has been already alluded to. Professor Church's Equation (33) is not quite a correct reproduction of the latter, for reasons already explained.

Two of the discussions, those of Professor Burr† and Mr. Janni,‡ criticize the principle itself, as to its correctness or value. Professor Burr has evidently not grasped the principle, and his discussion shows a number of misapprehensions. The principle is not restricted, as he thinks, to "that class of structures in which the axes of members are subject to angular displacement due to stresses of flexure or bending", but it applies to any structure, whether there is flexure or not, as illustrated in Case IV. Professor Burr, however, restricts his discussion to cases of flexure. His statement that the unit moment must be applied to each section is not correct, as is clearly shown by Case II.

* *Proceedings*, Am. Soc. C. E., May, 1919, p. 315.

† *Proceedings*, Am. Soc. C. E., September, 1919, p. 613.

‡ *Proceedings*, Am. Soc. C. E., September, 1919, p. 616.

Mr. Swain. The unit moment is only applied at the point where the rotation is desired. If the case is that of a beam fixed at one end and free at the other, and the rotation of the free end is desired, the unit moment applied there would cause a unit moment at every section, but this is not true for a beam supported at both ends or for a bar in a frame. Professor Burr's Equation (2), which he appears to think the correct form of the writer's Equation (4), by making $M_r = 1$, is in reality a totally different thing, for it gives the change of slope between two given points, while the writer's Equation (4) gives, as is clearly stated, the angular rotation at a given point. In a beam fixed at one end, his Equation (2) does, of course, give the angular rotation at the free end, but this is only because there is no rotation at the fixed end. His Equation (2), then, which he states gives the angular displacement of a point in the axis of a beam, only does so when the integration is extended from this point to some other point where the slope is not changed, and this point must first be found, unless its position is obvious, which is not generally the case.

The writer has made no analytical error, as Professor Burr claims. In his first illustration of what he considers this error, Professor Burr has perhaps been misled by the obvious typographical error in the writer's Equation (7), which should not have confused any one. In his second illustration of this error, Professor Burr finds his Equation (8), which is the same as the writer's Equation (4), for the case of a single beam in bending, and in which $d\alpha$ is, of course, the angular rotation only at the point where the unit moment is applied, and he then incorrectly uses this value as if it were the angular rotation at any point.

The writer's Equation (14), alluded to by Professor Burr, is of course the most general form of the Theorem of Three Moments only when the moment of inertia is constant. This is obvious, but perhaps it should have been stated in order that no one might have been misled.

To sum up, Professor Burr has evidently entirely failed to grasp the meaning or application of the principle. The fact, however, that he, who for so long has been an honored and leading member of the Profession, and at the head of one of our best engineering schools, was not only not familiar with the principle, but does not grasp it and denies its correctness when presented, should be sufficient to prove that the paper was needed, and quite a sufficient commentary on the remarks of Mr. Janni, whose discussion will now be considered.

Mr. Janni goes out of his way to find as much fault as he can with the principle and its presentation. Apparently, however, he has not succeeded in finding any ground for denying its correctness. He says it is "obsolete", not having yet perceived that a scientific principle, if correct, can never be obsolete. He says that "any good textbook will give some method of deriving this formula", but he wisely refrains

from naming any book which does. He thinks that "any student in any engineering school should know" the principle, and that it is "inferior to modern methods". He then proceeds to attempt to show how much better he could solve structural problems, and begins by stating a mysterious "mathematical truth" which gives the angular rotation of the free end of an elastic body fixed at the other end, using what is called "elastic weight" and "elastic center", terms introduced by Professor Ritter, of Zurich, thirty-two years ago, which, according to Mr. Janni's ideas, should be "obsolete" by this time. He refrains from demonstrating his mathematical truth, but does not state whether this is because "any student in any engineering school" should know it, or because it is too advanced and modern. If he had approached the discussion in a scientific or even courteous spirit, instead of simply trying to find fault, he might have perceived and pointed out that his "mathematical truth" is most easily demonstrated by the writer's principle, of which that truth is merely a corollary or application; but if the principle is obsolete, perhaps the corollary is also. Referring to his Fig. 33, and using the writer's principle, if a unit moment is applied at the free end the moment at any section is unity, and if y is the distance from the force P (applied at the free end) to any point of the axis of the piece, the moment at that section due to P is $P y$. Hence, by Equation (4) of the writer's paper Mr. Swain.

$$\alpha = \int_0^l \frac{P\, y\, d\, l}{E\, I} = P \int_0^l \frac{y\, d\, l}{E\, I},$$

or P times the distance from P to the center of gravity of all the $\frac{d\,l}{I\,E}$'s times the sum of all the $\frac{d\,l}{E\,I}$'s, or as he expresses it, $P\,G\,d$. This mysterious truth is, therefore, merely a corollary of the writer's principle of this particular case.

Now, it is always better to keep general principles in mind than corollaries, for the latter may be deduced at once if desired. In this way the memory will be relieved as much as possible, and any particular problem may be attacked in the manner best suited to the case.

It is easy now to take up the cases shown by Mr. Janni, and to show that they are either incorrectly solved by him or may be easily solved by the writer's principle, or other and well-known fundamental principles, without using elastic weight or any other conception, which may only complicate while giving the appearance of erudition. This is not said in derogation of the use of the "elastic weight", for no principle of science, and no corollary of one, ever becomes obsolete, but may at times be of use. The point is to emphasize the fundamentals.

Mr. Swain. Considering Mr. Janni's Case 1: This most elementary case of a beam of constant section fixed at one end is most easily solved by the area moment method, and the slope at the free end may be at once written down from the moment area, or $\frac{P\,l}{2}\,\frac{l}{E\,I}$. The writer's principle is precisely the same, since $M_r = 1$. Elastic weight, therefore, is unnecessary and also confusing here. If the section is not constant, the writer's Equation (7) may be at once written, without the last term, and $\alpha = P$ (sum of each $\frac{d\,x}{E\,I}$ multiplied by its x); while Mr. Janni would have us first find the d of the center of gravity of the $\frac{d\,x}{E\,I}$'s by finding the quantity in parentheses above, and dividing it by the sum of all the $\frac{d\,x}{E\,I}$'s, and then multiplying by this same sum. The elastic weight is here neither necessary nor desirable, but merely a complication, as "any student in any engineering school" can easily see. Treating Mr. Janni's second case by the writer's method, a left-handed unit moment applied at D would cause a unit moment at every section of the three parts, and no direct stress. The load P produces direct stresses as well as moments, but as the writer explained in his paper, the former are not to be considered. Resolving P at D into horizontal and vertical components H and V, the moments produced by P are:

In DB, a moment varying from zero at D to Hh at B;
In BA, a moment varying from Hh at B to $(Hh - Vl)$ at A;
In AC, a moment varying from $(Hh - Vl)$ at B (causing compression on the left-hand fibers), to Vl at C (causing compression on the right-hand fibers).

The value of the angular rotation at D may at once be written, observing signs, as

$$E\,I\,\alpha = \frac{H\,h^2}{2} + H\,h\,l - \frac{V\,l^2}{2} + H\,h^2 - V\,h\,l - \frac{H\,h^2}{2}$$

$$= H\,h\,(l + h) - \frac{V\,l}{2}\,(l + 2\,h).$$

If the load P is under control it may sometimes be of use to recognize that, if it passes through the point G, α will be zero, but this is shown just as simply by the ratio of V to H given by the above equation, as by finding G.

Mr. Janni's Case 3 is the same as that illustrated by Fig. 33 and the writer has already shown that his principle gives the solution more simply and easily than Mr. Janni's method. Referring to his Case 4,

if we observe what Mr. Janni's method really is, we shall see that it is inaccurate, and that so far as it is correct it is merely a "camouflaged" application of very old principles. To find the angular rotation of the bar B at the point 13 under a force F at 13, it is clear that the lower chord bars will be in compression and the upper chord bars in tension. Any shortening of the distance 1-3 will cause a rotation about the point 2, and if S is the stress in 1-3, the shortening will be $\frac{S\,l}{E\,A}$ and the angular rotation about 2 will be $\frac{S\,l}{E\,A\,r}$. For a load F at 13, the value of S will be $\frac{F\,a_2}{r}$ if a_2 is the distance from 2 to F, hence the angular rotation will be $\frac{F\,l\,a_2}{E\,A\,r^2}$, and this rotation will affect all the structure beyond 2. The same is true for each chord bar, all rotations being in this case in the same direction; hence the total angular rotation of B will be $F\,\Sigma\,\frac{l\,a}{E\,A\,r^2}$, in which a is the distance of any point from F, and l the length of the chord bar opposite the joint, E and A its modulus of elasticity and area, and r its distance from the joint. If a force $\frac{l}{E\,A\,r^2}$ is considered to act at the joint opposite l, this angular rotation is merely F (sum of moments of these forces about any point in the line of F). This sum may be found by the elementary principle of graphical statics, by drawing the string polygon for these loads, drawing through the point about which the moment is desired a vertical line (that is, prolonging F), and finding the intercept, y, between the end strings. The moment will be the pole distance times y, and by taking the pole distance as $\sum \frac{l}{E\,A\,r^2} = G$, then $G\,y$ is the moment, and this times F is the rotation. Mr. Swain.

This is not modern, but is merely using Culmann's principle of finding moments graphically. One wonders that Mr. Janni did not consider this principle obsolete. Mr. Janni's application, however, is erroneous, because he neglects all the web members. In solid beams, the deformation due to shear is often or generally neglected because (1) it cannot be accurately determined, and (2) it is often or generally small. In trusses, the deformation due to shear may be determined as accurately as for the chords, and it may be considerable. Professor Ritter cites a case in which the deflection due to web members was 41% of the total. There is no excuse here for neglecting the web. By the writer's principle, the stress in every member would be found; the unit moment being applied at 13, the stress in every chord piece due to it would

Mr. Swain.

be $\frac{1}{r}$ and the stress due to F would be $F\,a \div r$. The web would be similarly included. The summations may be made more quickly, easily, and much more accurately than by Mr. Janni's method, which does not and cannot well include the web, and which is therefore distinctly inferior. This example well illustrates the danger of using methods that one does not thoroughly understand, and the importance of grasping and adhering to fundamental principles.

The writer cordially thanks Messrs. Hudson, Mensch, Eddy, Cain, and Maney for their interesting contributions, which call for no specific comment.

To sum up, it is no doubt true, as pointed out by Messrs. Church, Eddy, Cain, and Mensch, that the writer's principle is implicitly contained in Castigliano's work equation. So was the latter implicitly contained in the law of the conservation of energy, and the principles of dynamics in Newton's laws of motion. The writer, however, has not found in Castigliano any statement of this principle of rotation. He admits that the principle as applied to beams was known in Europe, but he has not found it explained in any American book, neither in Church, Molitor, Turneaure, Hudson, nor any other. Further, he still fails to see that any author, anywhere, has clearly shown its general applicability, to trusses as well as to beams, or even stated it, as a principle analogous to the deflection principle of Maxwell. Hence, he still thinks it may be called new.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

CONTRACTS—A COMPARISON OF "COST PLUS" WITH OTHER FORMS

Discussion*

By Ernest Wilder Clarke, M. Am. Soc. C. E.†

Ernest Wilder Clarke,‡ M. Am. Soc. C. E. (by letter).§—As stated at the time of presenting the paper the writer was principally anxious to induce discussion on a subject which seemed to him to be worth it, especially at this time, and he hoped that such discussion might bring out statements that would indicate the wisdom or otherwise of a more general use of the "cost plus" contract. Unfortunately, with one exception, there has been little but expressions of personal opinion which, while interesting and instructive, are not proof either for or against this form of contract, and he does not consider it worth while to continue to great length further discussion based on such grounds. Mr. Clarke.

Conditions during the war were so abnormal that excessive costs of work should not be charged to any form of contract—organizations for supervision were improvised over night and naturally did not function smoothly at once. The contractors' organizations were also greatly expanded to care for the vast increase in their work, and inevitably the two organizations failed, in many cases, to evolve the cheapest methods of doing the work. As the war went on, this handicap was largely overcome, and there were many cases where the supervising engineers and their forces and the contractors and their forces worked together most successfully to devise means to reduce the cost of the work. The high cost of labor and material largely masked such

* Discussion of the paper by Ernest Wilder Clarke, M. Am. Soc. C. E., continued from February, 1920, *Proceedings*.

† Author's closure.

‡ Baltimore, Md.

§ Received by the Secretary, March 26th, 1920.

Mr. Clarke. efforts, however, and very little credit will ever be given for real economies effected in spite of adverse conditions. In other words, war-time costs were so far above those of peace times that the fact that they might have been still higher except for the efforts made by the two parties is not appreciated. The contractors are blamed for things of which they really were the victims and over which they had no control. Mr. Frankland states* that "this form of contract would 'smell to high heaven'" on some "cost plus" contracts. If this statement is true, it implies connivance on the part of the supervising forces or at least such disregard of their obvious duty that it amounts to connivance, and any one having proof of such conditions should bring the facts to the attention of officers who could punish the guilty persons.

This is not the place to enter into a discussion of the causes of the high costs of war construction, but as the writer had intimate knowledge of conditions on a dozen or more large and small "cost plus" jobs, with large and small contractors at work during 1917 and 1918, he feels himself competent to assert that after the organizations reached a good working condition both parties to the contracts did everything possible to make the work as inexpensive as conditions of the market permitted, and that intentional loading of the pay-roll, loafing on the job, or unnecessary purchases, were neither permitted nor attempted, the contractors' foremen being generally as zealous in crowding their men as on lump-sum and with-price jobs.

The writer does not agree that the use of "cost plus" contracts is an admission of inability to write clear and specific specifications. He had the honor to assist in writing some of the specifications of the New York Board of Water Supply, and is familiar with the extreme care used in order to make those specifications clear and fair to both the city and the contractor; almost every word was scrutinized for an ambiguous meaning, and where any doubt existed as to the exact meaning explanatory phrases were introduced or other more definite word or words substituted. Later, he was in charge of construction under these specifications and learned how many different interpretations contractors' superintendents and engineers could propose for words which he supposed had only one meaning. Most of these disputes were settled amicably, but they were all potential suits, and the mere fact that they were possible is indicative of the extreme difficulty of writing specifications that will prevent misunderstandings. This is not intended as an argument for the elimination of specifications, but merely as indicating that disputes are not always due to carelessly drawn specifications.

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* *Proceedings*, Am. Soc. C. E., October-November-December, 1919, p. 833.

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The writer still believes that an engineer is, and properly is, "biased" in favor of his employer, the owner; the engineer is hired for the specific purpose of protecting the owner against the contractor's errors, whether or not such errors are intentional, and it is his duty to require the contractor to prove the justice of any claim involving the reading of the contract or specifications; the fact that in many cases the contractor is able to satisfy the engineer that his claims are just and that in such cases the engineer has fought to secure the acknowledgment by the owner of the claims merely accentuates the fact of the prior bias of the engineer.

The one discussion which gave the result of experience with lump-sum and "cost plus" contracts is the best evidence that the latter form, when handled by intelligent and honest contractors, is favorable for both sides to the contract. Presumably, the owners of the jobs covered by Mr. Perry's discussion* had engineers or architects representing them and, doubtless, some of these men made suggestions or even ordered methods that resulted in decreased costs.

Engineers are apt to assume a rather sanctimonious attitude toward contractors, to hold that engineers are honest, but that contractors require strict watching to prevent very serious wrong-doing. As a matter of fact, intelligent self-interest forces a reputable contractor to do work which will bear inspection and which will serve as an advertisement of good work and not bad. As men, they are, nowadays, of the same class and education as engineers, and have as high a sense of honor. The writer has had the pleasure of knowing many contractors whose simple word is a guarantee of faithful work and, with such men, the engineer's part on the job is largely that of staking out the work, interpreting the plans and specifications when any ambiguity is discovered, and, in general, making inspections to see that mistakes are not made.

All engineers are expected, and practically all do, work against their own financial interests. Almost invariably they are supposed to push the job in every way they can, to work overtime without any extra pay in order to avoid delay in the work; to order their work so that the construction is not held up—in short to do everything possible to get themselves out of a job and have a chance to hunt for another on their own time.

The writer has yet to find a gang which, as a whole, failed to live up to the expectation that it would in this way work against its immediate and most apparent interest, and he believes that another gang which is different only that it is employed by a contractor would perform in the same way, if its chief made it plain that he expected such an attitude, and many contractors have and would make it very

* *Proceedings*, Am. Soc. C. E., October-November-December, 1919, p. 844.

Mr. Clarke. plain that that was their expectation. A reputation for such an attitude would be the best guarantee the contractor and his forces could have that, good times or bad, owners would offer them work and that, unlike the engineer, neither the contractor nor his men would have to hunt for work on their own time.

As for the engineer, the "cost plus" offers him a chance to show both executive and constructive ability—to make it evident to the owner that he has saved money for him by methods whereby costs have been reduced, by taking advantage of favorable developments of the site, or by overcoming unfavorable developments at minimum expense.

As chief inspectors, engineers now get credit at the most for negative results—they prevent bad work. It is utterly impossible to evaluate such service in dollars, and little effort is made to do so; their services as designers are largely forgotten after the plans are accepted and work begun and the owner regards them as he regards insurance, as an overhead expense to be cut to the minimum possible. The contractor often thinks that engineers are more or less impractical theorists with whom he has to put up, but who can cause him much loss by insisting on contract or specification interpretations which, to his mind, are unreasonable.

As a matter of fact, on jobs of any size, the engineer is generally the man best informed as to local conditions, methods of work likely to produce good results at minimum expense, and plant required. He has spent weeks, months, possibly years, studying the plans and the site and has a fund of knowledge that is only partly reflected in the plans and specifications. After a lump-sum or item contract is let, the contractor, if he is wise, consults with the engineer and revises his own plans and methods as far as he is convinced of the soundness of the engineer's ideas. Any saving made from such revision generally goes into the contractor's pocket. The owner may gain indirectly by increased speed, but the knowledge of his employee principally benefits the contractor. On a "cost plus" contract, where the owner and the contractor are working in harmony, the engineer becomes a vital part of the machinery. His knowledge and his experience are direct assets to the owner, the contractor, and himself; he ceases to be a spectator of the construction of the work he designs, and is an active participant in methods, plant layout, and responsibility. The writer believes that in endeavoring to relieve owners of responsibility for the contractor's acts, engineers have also relieved themselves so entirely that they have become mere layers out of work to a large degree, and, as such, receive the wages of subordinates instead of the rewards of creators.

It goes without saying that no one form of contract would apply to all work, and this appeared so self-evident that the point was not

Mr. Clarke.

mentioned in the paper. The generic term "cost plus" was also used because it was recognized that many possible forms of this type existed and many more could be written, although the paper was not an advocate of any particular form. A form such as Mr. Waddell* suggests might be applicable to some contracts, other forms to other contracts.

Many schemes for "letting" whereby competition would be secured and the elimination of new firms avoided could be evolved. The engineer's estimate of probable cost would be expected to show the owner in advance the approximate amount of money involved and with the engineer as the owner's representative in full control of expenditures, it would be his duty to keep the expenditures within that limit or explain the reason for failure to do so. It would also be to the engineer's credit if savings were made, and a reputation for ability to keep ultimate costs below the estimate would enable him to demand adequate payment for such service.

The statement has been made repeatedly that under a "cost plus" contract the contractor has no incentive to save money for the owner. This statement does not do credit to the contractor's business sense.

Firms looking for work under such contracts must be able to refer a prospective client to the owners of jobs they have done and be able to show by the cost records of such jobs that economy was effected, otherwise their first job would be their last. As a matter of fact, a record of low costs becomes the most valuable asset of such a contractor and of far more importance than the money that might be made on one or two jobs by running the cost into high figures. The owner is supposed to exercise care in the selection of a contractor and to have the work properly supervised. If he does neither of these things, he may pay a very high price for his structure, but such an owner would be just as likely to be cheated on a lump-sum or item contract.

The use of the "cost plus" form on public work is evidently a much more dangerous thing than on private work, but only on account of the political complication. If experience proves that the form is economical for private owners, some scheme could be devised by which the public also could be benefited.

Some contractors may "enjoy the gamble", but probably they enjoy it the most when they are sure they will not lose; where they have added enough to their item charges or their lump-sum to provide for anything short of a general cataclysm and have been awarded the job not on account of their optimism but because of the greater pessimism of the other bidders.

In the long run, nobody is benefited by a business failure. Some owner may get a job done below cost, but workmen and supply men suffer, and wherever possible the loss is passed on to some other job.

* *Proceedings*, Am. Soc. C. E., October-November-December, 1919, p. 867.

Mr. Clarke.

Any scheme that tends to prevent failures is a step in the right direction, provided new dangers are not thereby introduced, and "cost plus" contracts can be written and applied so that these new dangers are avoided to a great extent.

If the paper and discussion has the effect of bringing the matter more generally to the attention of engineers, the writer's object is attained. He believes that the "cost plus" contract in one form or another is suitable for use on many jobs and that its use would result in good for owner, contractor, and engineer.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

GROUTING OPERATIONS, CATSKILL WATER SUPPLY

Discussion*

By Messrs. Milton H. Freeman, C. L. Riker, Jr., and Benjamin A. Howes.

Milton H. Freeman,† M. Am. Soc. C. E.—The authors of the paper deserve credit for presenting data of great value. Such data are most difficult to obtain as they involve many trials and experiments on work of considerable magnitude. The following detail considerations are submitted as being of possible interest. Mr. Freeman.

Placing and Protecting Grout Pipes.—Reference has been made to the necessity of a good concrete lining in order to make grouting a success in securing a water-tight tunnel, and it may be of interest to consider some particular features relative to the placing and protection of grout pipes as an aid in securing good concrete. The placing of pans and pipes subsequently to be grouted requires the utmost care and forethought; they should be placed with some method in mind for finally filling them with grout, not simply with the idea of taking care of incoming water. A careful record should be made showing what particular function each pipe serves at the rock end so that, later, grouting can be done intelligently. Pipes are sometimes disturbed by the placing of a heavy mass of concrete, and a most careful inspection of these pipes is necessary during concreting. All drain pipes, of necessity, have to be brought through the forms, and it is far better if the vent pipes are placed in this way so that they may be cleared of any concrete that may become lodged in them while the concrete is still soft. Pipes draining large leaks usually free themselves of any mortar that may

* Discussion of the paper by James F. Sanborn, M. Am. Soc. C. E., and M. E. Zipser, Assoc. M. Am. Soc. C. E., continued from March, 1920, *Proceedings*.

† Valhalla, N. Y.

Mr. Freeman. work in from the concrete, but pipes set to drain small drips are easily clogged, and it is not an uncommon experience to find one that was placed to pick up a small drip perfectly dry, while the leak finds its way through the body of the concrete at some nearby point. A material aid in such cases is the washing out of the bottom of the drain pipe by inserting a small (½-in.) pipe connected to the water line, or air line if water is not available, after the manner of blowing out drill holes before loading in a rock heading. This must be done with extreme care after the concrete is from 1 to 2 ft. above the rock end of the pipe. This procedure has often saved pipes that started to clog at the rock end.

Shaft Ring Pans.—The ring pans in shafts, as described by the authors, have a double service: First, they furnish channels for grouting any shrinkage cracks between the concrete and the rock and possibly cracks in the rock itself; second, and probably their most positive function is to collect seepages that are not easily discernible, and consequently are not taken care of with individual pans on the wet sides of a dripping shaft, and which follow up behind the concrete until collected in the ring pan. Where these pans have been used, it is a most common occurrence to find the down drain pipes dripping after all the concrete has been placed. Since leaving the work on the Aqueduct the speaker has found in certain instances, where shaft lining has been placed without the use of these pans, that there is a greater tendency to leakage at horizontal joints. The pans are preventatives against such leaks.

It has been thought by some that it might be worth while first to grout these rings with thin grout under high pressure, to penetrate the rock seams, and afterward blow them out and close them with thick grout.

Displacing Water with Grout.—Recently the speaker has had occasion to do some grouting where water had to be displaced by grout, and found that when the volume of cement to be injected is comparatively small and the necessary grouting pressures not excessive (60 to 80 lb.) the hand pump has proved to be of excellent service, as it is under instant control, wholly eliminates the ill effects of the after-blast of air, and displaces the water by grout without disturbing and mixing the two. From 100 to 150 bags of cement can be injected with the hand pump per 8-hour shift, under favorable conditions. Grouting to displace water with an air-discharging grout tank is most difficult to accomplish without the formation of considerable laitance. Shutting off the tank pressure when the hose kicks or when the tank gauge pressure drops is of value, but when this phenomenon takes place, a charge of air has already gone through the hose, to stir up the grout with the overlying water. Keeping the grouting pressure as low as possible is a worth-while precaution, even at the expense of clogging the hose once in a while.

Mr. Freeman.

Volume of Set Grout in Place.—The question of the ratio between the volume of mixed grout and the volume of set grout in place is often required, sometimes as a payment quantity. The contracts of the Board of Water Supply very wisely avoided this, as it has been found that there is no fixed, definite ratio. Not only does the volume vary with the quantity of water and the quantity and kind of sand used, but the degree to which the grout mass is shaken in the process of placing. Experiments on small quantities indicate that, due to the latter cause alone, a variation of 20% may be found. If necessary to determine this ratio, experiments involving the particular kind and quantity of sand used and the quantity of water utilized for mixing will probably give the most reliable data.

Grouting Overhead Closures.—One feature of grouting which may be of interest is the method of making overhead closures where the surplus water from the grout is trapped, that is, cannot be disposed of by increasing the grouting pressure. Concrete structures are often built up under other structures, where it is essential to secure a good bearing, possibly a joint that will be water-tight. A concrete arch placed inside a steel or iron lining is another illustration.

Certain features in regard to this kind of grouting have been worked out as follows:

1.—The thicker the grout the less surplus water will be thrown off.

2.—Practically all this surplus water is thrown off and pools form on the top of the grout within one hour after placing.

3.—If sand is used, the presence of a small quantity of loam (as little as 5%) increases noticeably the amount of laitance at the top.

4.—A second, third or possibly a fourth grouting may be necessary finally to fill the space occupied by the surplus water from the grout ejected previously.

5.—Vent pipes should be set to take advantage of any small summits; if the overhead structure is of concrete, summits may be chipped out. Arch or roof concrete forms often sag when concrete is placed on them, but the vent pipes should not be allowed to sag with the forms.

If all pipes are cleaned out as soon as the grout has partly set, the same pipes can be used for subsequent groutings. This necessitates individual vent pipes to each summit. A second grouting usually leaves only a very small space unfilled, but sometimes grout can be injected at a third or fourth trial. Neat cement grout is commonly used after the first grouting. Higher pressures can be used with advantage as the space fills up, if the structures themselves are strong enough to withstand such pressures. The foregoing, of course, applies only to places

Mr. Freeman. where it is essential to obtain a complete contact between the two structures.

Grouting Undisturbed Sand.—Several attempts to grout undisturbed sand have come under the speaker's notice, but all such attempts were ineffectual, even though thin grout and high pressures were used. A little cement can sometimes be injected into gravel that contains no fine sand as a filling material.

Mr. Riker. C. L. Riker, Jr.,* Assoc. M. Am. Soc. C. E.—High-pressure grouting operations were resorted to on the lining of about 1 200 ft. of the Catskill Aqueduct in the section south of Twenty-fifth Street, New York City, following the development of outward leaks through numerous small cracks which opened in the concrete lining during the initial hydraulic test of this section. These cracks were due to the compression or shifting of the soft seamy rock through which this section of the tunnel passed.

This section had previously been grouted by the use of both low and high pressures, but numerous hair cracks in the lining indicated that the original high-pressure grouting had not penetrated the minute seams of the rocks a sufficient distance or thoroughly sealed and formed an unyielding backing to the lining. Ground-water flowed freely from many of these cracks. It was necessary, of course, to stop this flow entirely prior to commencing grouting operations. These leaks were effectively stopped by chipping out a groove along the line of the crack and caulking the groove with lead wire.

Threaded pipes, 1½ in. in diameter, were rolled tightly with cotton drill and driven into 2¼-in. holes bored in the concrete lining. This formed an entirely satisfactory and tight joint between the pipe and the tunnel lining.

In regrouting this section, 9 500 ft. of 2¼-in. hole, or a little less than 8 ft. of hole per foot of tunnel, was driven, and 2 400 connections were made to these holes, or 2 connections per foot of tunnel treated. More than one connection was made to many of the pipes, and some were only used for venting purposes. About 44 000 cu. ft. of very thin liquid grout was forced through these connections, using from 250 to 350 lb. per sq. in. air pressure at the displacement tank.

Generally speaking, apparently the grout was effectively prevented from re-entering the tunnel. However, a peculiar substance incident to the grouting accumulated within the tunnel. A heavy grayish custard-like mass was formed, which, when quiescent, became almost as hard as cheese; when agitated it became soft and liquid, and was carried in solution by a sluggish flow of water in the invert. A settling basin was formed on a slope down stream from the grouting operations, and

* Brooklyn, N. Y.

about 800 cu. yd. of this soft waste matter accumulated as a result of 45 000 cu. ft. of liquid grouting. Mr. Riker.

A considerable amount of solidified droppings accumulated adjacent to the grout tanks, caused by spillage, venting, and blowing out the grout hose. Apparently, most of the grout so wasted solidified adjacent to the grout machine even though dropped into the slowly flowing water in the invert as well as on the lower quarters of the tunnel.

It is hard to account for the enormous quantity of this custard-like material, and it would be interesting to know whether the grouting process generally results in similar waste products, and, if so, of what this waste material consists.

Benjamin A. Howes,* Assoc. M. Am. Soc. C. E.—An important point as to the fine grinding of cement is involved. Theoretically, as the authors intimate, it would seem that very finely ground cement would percolate more readily into the finer cracks and crevices as grout. Likewise, it would seem that if the cement were ground extremely fine, it could be carried into the interstices of sand and gravel as grout to consolidate them in place. The authors' statement indicates that experience shows this to be impossible and that standard fineness has been found to be more practical. Mr. Howes.

The mechanical features of setting and hardening explain this seeming clash between theory and practice. The finest particles are hydrated by the mixing water almost immediately, because the water reaches the entire mass at once. Particles of appreciable size are reached by the water only on the exterior surface, and hydration proceeds by the attack of successive layers and to some extent by percolation of water into crevices of the particles. Ordinarily, the still coarser particles are hydrated on their exterior surfaces only, and these coarser particles with some 10 or 15% of inert constituents often comprise 40% of the cement. They act as reserves or factors of safety and will hydrate in time if needed to consolidate the mass.

Therefore, for grouting it is essential that a large part of the cement be ground so coarsely that it will not hydrate until it has reached its final resting place and will then by slow hydration consolidate the fluid that has been the carrier.

When a porous tunnel lining is under air pressure, grout will carry the coarse particles into the pores to some extent and there they will hydrate and stop the flow of air or water, but this only in very small degree fills and consolidates the total porosity. There is one place where these reserves of coarse particles demonstrate their office very plainly—in the case of small cracks in a concrete wall retaining water. Sometimes the cement reserves seal the crack in place and sometimes

* New York City.

Mr. Howes. percolating water brings dissolved cement to the surface, where evaporation condenses it to seal the crack.

The speaker has found these unhydrated coarse particles of cement in hydraulic structures years after construction. In one case a tunnel lining, in another, a dam which had been in use 4 or 5 years showed unhydrated particles of cement from $\frac{1}{1000}$ in. to $\frac{1}{2000}$ in. in diameter. These particles had the characteristic cellular structure of Portland cement clinker. Hydration had taken place around the surface of the particles, and the interiors of such particles appeared to be ready to hydrate if water were introduced through a crack or otherwise.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE "LIGHT RAILWAYS" OF THE BATTLE FRONT IN FRANCE

Discussion*

By Messrs. H. F. Dunham, Morris E. Pumphrey, Hazen L. Hoyt, Jr., W. B. Poland, and Marshall R. Pugh.

H. F. Dunham,† M. Am. Soc. C. E.—The speaker wishes this paper had been extended to include facts relating to the traffic and operation of trains on so narrow a gauge. The author when concluding the discussion may mention difficulties that do not pertain to transportation on standard gauge lines. **Mr. Dunham.**

Col. James B. Dillard, U. S. A., read a paper before the American Society of Mechanical Engineers, on December 5th, 1918, from which the following paragraph is quoted:

"The 1918-model, 8-in. gun, railway mount which uses the same barbette carriage as the 7-in. gun may be elevated from 0 to 42 degrees. It fires either a 200 or 300-lb. projectile at a maximum velocity of 2 000 ft. per sec. and has a maximum range of about 69 000 ft. By means of special 8-wheel trucks it is possible to transport this mount over a 60-cm. (24-in.) narrow gauge track. This 8-in. mount weighs about 180 000 lb. and it certainly is a great advantage to be able to transfer it to a narrow-gauge track which is the kind used at the battle-front in order to better conceal operations. On the narrow-gauge track a speed up to 15 miles per hour is feasible. The Ordnance Department which developed this mount in its entirety considers this artillery piece to be the last word in railway mounts. It is also the only mount of its kind in existence."

Any further description of such unexpected loading and service would be especially interesting.

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* Discussion of the paper by Frank G. Jonah, M. Am. Soc. C. E., continued from March, 1920, *Proceedings*.

† New York City.

Mr. Dunham. There are now many miles of 2-ft. gauge railroad in use in the United States, not as logging or factory-yard roads, but as veritable railroads serving many communities and functioning in all respects like a standard gauge steam road except that freight, passenger, and drawing-room cars are not exchanged, but always remain on their own tracks. Cars are not lost and a company can do its own repairing.

The Bridgeton and Saco River Railroad,* more than 20 miles in length, is a narrow (2-ft.) gauge road of this type, which connects Bridgeton Junction on the Maine Central Railroad with Bridgeton and Harrison, Me. The alignment includes one 36° curve, one 20° curve, and others of longer radius. The grades reach a maximum of 4% for short distances. The road operates 5 locomotives, 6 freight and passenger cars, and a total of 72 cars. The locomotives weigh from 22 to 36 tons each. These engines have two driving axles about 54 in. apart, a one-axle pony truck and tender on the engine frame extended. The freight cars are more than 33 ft. in length, 6 ft. wide and 6 ft. high in the clear, weighing 7½ tons, and carry a net load of 15 tons. The noticeable difference in the passenger car is the "one-seat" feature on each side of the central aisle. The average speed is more than 20 miles per hour.

This road was built prior to 1888 and for many years before the World-War disturbance and high prices, it had paid regular dividends. In 1915 it carried 34 500 passengers and 31 500 tons of freight. These figures, however, do not show the great value of the road to those residents who without it would be shut off from the outside world for long periods. Its trains are said to be always waiting for the Maine Central trains in the intervals of trouble from deep snows; in fact, the narrow gauge is said to be an advantage in heavy drifts.

From Farmington, Me., in a northerly direction, the Sandy River and Rangeley Lakes Railroad of 2-ft. gauge has now 106 miles of similar roadbed and track and 16 miles of sidings. This road operates 14 locomotives, 18 passenger cars, and a total of over 300 cars, and the revenues from operation in 1918 were $234 955. The weight of rail varies from 25 to 58 lb. per yd.

A traveler on these narrow-gauge roads is not subjected to hardship, and records do not indicate added risks. Extra fare insures a seat in the drawing-room or chair car and the principal difference in the passenger's sensations is a feeling that the ground is not far away. The low center of gravity makes for safety. When cheaper motive power, for example, hydro-electric and storage battery service, can be provided, such 2-ft. gauge lines should become more numerous where there is not business enough to justify standard gauge construction.

* The speaker illustrated his remarks by a moving picture film showing locomotives, cars and roadbed of this railroad.

MORRIS E. PUMPHREY,* Esq.—The speaker was with the 21st Engineers at Sorcy, Meuse, which place has been described by the author, from March to October, 1918. Afterward he was in the Argonne, and it is thought that a few details of his experiences may be of interest. Mr. Pumphrey.

One of his first duties upon arrival at the front was to make a reconnaissance for the purpose of connecting the light railway lines in the St. Mihiel Sector with the German lines, in case of advance. This plan was properly studied and prior to the St. Mihiel advance, large quantities of light railway material were brought up adjacent to the front line trenches. On the morning of September 12th, 1918, preparations had been completed for the laying of the tracks across "No Man's Land", as soon as the infantry had advanced.

The speaker was located at a town called Flirey, about 400 yd. from the front line trenches, where he had one company of experienced light railway troops, with one company of negro labor troops, which had just arrived in France and had had no experience with construction work. These were the only troops available for this work and were totally insufficient in number. On the morning of September 12th, the infantry went over the top about 5 o'clock and the engineering troops immediately started to construct the light railway across "No Man's Land". As the infantry advanced, a party of experienced engineers laid out the line on the ground and marked it with the white trench tape. As may be imagined, this line was very uneven and lacked a great deal in the way of uniform grades and curves. At this point 4 km. of track had to be built. Due to the shortage of labor and lack of ballast, it required 4 days to get this line in operation, whereas it should have been built in 12 hours in order to have been of real use to the combatant troops.

After this line was completed, the regiment to which the speaker was assigned was moved to the Argonne Sector, where no light railway troops had been available before. The Argonne advance began on September 26th, 1918, but it was almost the middle of October before any definite headway had been made in connecting the American light railways with the German lines. This was due to an insufficient number of troops, lack of material, and a great lack of proper planning before this operation was put into effect. By November 1st, the light railways in this sector had been well connected up and traffic was operating smoothly. As the combatant troops advanced November 1st, for the final phase of the Argonne battle, more light railway troops and material had been made available, so that for a few days it was possible to maintain connections with the advancing infantry, but by November 11th, the infantry had advanced so far that the line of supplies had almost collapsed. On November 11th, supplies were being hauled on one line for a distance of 55 km. and on another for a distance of 60

* New York City.

Mr. Pumphrey. km. Both these lines were handling approximately 1 000 tons per day of rations and ammunition.

The locomotives which were furnished for light railway work proved to be very unsatisfactory, the steam locomotive being top-heavy. The speaker recalls the case of one Captain in the regiment who re-railed 65 of these locomotives in 1 month, which would seem to be a record. The gasoline tractors worked very well at times, but generally failed at the crucial moment.

It was found that curves with a radius of 50 m. are as sharp as should be used and that no grades exceeding 3% should be considered. Recently, in one of the engineering papers, some writer has suggested the advisability of adopting wooden ties, instead of steel ties for sectional track such as was used by the Armies engaged at the front. It was quite right to use the wooden ties on back lines where there was ample time for the construction of first-class track, but it certainly would not be advisable to use wooden ties near the front, on account of the delay in transporting them.

The speaker is firmly of the opinion that the 20-lb. rail used by the English is the ideal rail for the 60-cm. railways. However, it is understood that the engineers of the War Department are recommending a 25-lb. rail.

During the early part of 1918 the speaker made a detailed study of the French light railway system from St. Mihiel to St. Die in the Vosges Mountains and found that sharp curvature and heavy grades were common on the French railways, that the road-bed as a rule was too narrow, and that insufficient ballast was provided to make a good track, although in numerous cases masonry retaining walls and culverts which would be a credit to the standard railways in the United States were found. This work, as can readily be imagined, was absolutely unnecessary in war-time construction.

Mr. Hoyt. HAZEN L. HOYT, JR.,* ESQ.—If the American people are to derive any benefits from the World War, it must be by profiting by the lessons learned both at home and abroad. It is necessary, therefore, that the good and bad points of the different services and departments be carefully weighed before drawing conclusions, and this is true of the light railways of the battle fronts in France.

The author has given a clear idea of the types of equipment used abroad and of the work done by the light railways, in France, but he has failed to bring out wherein they failed in their functions.

At the outbreak of the war many kilometers of military railways existed in France, principally in and around the permanent fortifications of that country, and it is, therefore, only natural that when the fighting settled down to what was known as a "warfare of position"

* New York City.

that these railways should be extended to help supply the troops in the line, especially as motor-truck transportation has never been developed abroad to the extent that it has in the United States. However, the Allies soon realized the need of this form of transportation, and large orders were placed both at home and abroad to supply this demand. Mr. Hoyt.

When the United States entered the war these 60-cm. railway lines were well established, and portions of them were taken over by the Americans with the sectors assigned to them. The railway locomotives used by the Americans in France were manufactured by the Baldwin Locomotive Works, as stated by the author, but, in the speaker's opinion, proved to be absolutely unsuited to the service they were called on to perform. The steam locomotives were entirely too high, had insufficient steam capacity, and were badly adapted to the kind of coal they had to use. The spring suspension was poor and only 68% of the weight of the locomotives was carried on the drivers. The over-all length was too great in proportion to the rigid wheel base, causing the rear drivers to pull off the rails when hauling heavy trains around sharp curves. Although these locomotives were designed to negotiate 30-m. curves, it was found that 40-m. curves had to be adopted as the minimum and curves of 50 m. were used where possible. Why this type of locomotive should have been adopted, the speaker is at a loss to understand, as double-truck steam locomotives had been manufactured in this country for the Allied Governments prior to the entry into the war by the United States and had proved entirely satisfactory. So poor was the ability of these locomotives to stay on the track, that one company of the 21st Engineers operating and maintaining approximately 50 km. of track during the Argonne Drive had to re-rail 65 locomotives in 1 month.

The gasoline locomotives worked better as far as their ability to stay on the track was concerned, but the standard of workmanship and material was low, and mechanical troubles were constantly arising, principally with the clutch and gear case. The spring suspension also was poor which, combined with the large overhung weight at either end, caused a jumping effect at high speed, frequently resulting in derailment.

The cars were far too heavy for their load capacity and trouble was constantly being experienced with the draw-bars, due largely to the great amount of side play allowed, resulting in frequent instances of broken draw-bars when coupling up the trains. If a four-wheel car of half the capacity had been adopted, the weight could have been reduced by nearly two-thirds, besides such cars would have been far easier to re-rail than the eight-wheel double-truck type furnished.

The author states that both the English and French Armies had found that it took approximately 21 000 man-hours to build 1 mile of 60-cm. track. In this connection, it would be well to give some figures of the work done by the 11th Engineers during the Cambrai Drive in

Mr. Hoyt. November, 1917. Working in conjunction with about 350 men of the 4th Battalion of Canadian Railway Engineers, 300 men of the 11th Engineers laid approximately 10 miles of standard-gauge track in $7\frac{1}{2}$ days, from Epehy to Marcoign. The best time was made by the Americans, who laid $1\frac{1}{4}$ miles of track in 5 hours and 46 min. This work consisted in re-laying the rails and ties, filling in shell holes, mine craters, blown-out culverts, trenches, etc., the ballast being already in place as the line followed along the old right of way of the Nord Railroad, running from Peronne to Cambrai.

Another matter which caused endless trouble for the troops operating the light railways, was the voluminous reports required by the Department of Light Railways, many of which it was impossible to supply and almost all of which could not be given accurately, due to the conditions of operation. This was particularly true of the reports on coal and gasoline consumed, as much of this material was obtained from captured German dumps and the quantity could only be approximated, as no weighing apparatus was available.

Another source of annoyance was the difficulty, if not impossibility, of securing permission to change the equipment in any way, as this meant a change in the standards. Many of these changes were minor, but would have helped materially in the operation of the trains and could have been done easily by the troops themselves had permission been granted.

As stated by the author, the main shops of the light railways were located at Abainville, almost directly back of the center of the Toul Sector; this town also was the supply base for the light railways. Until the lines started to advance it served its purpose very well, or would have, had the shops been completed. After the First Army moved to the Argonne, however, this base was about 70 to 80 km. away by road and nearly twice that distance by rail, requiring nearly three days' travel by rail and almost a day by road in order to obtain supplies. Even when these supplies arrived at the light railway shops of the First Army, at Dombasle (in Argonne), they were nearly 60 km. from the advanced railway companies.

These were the conditions existing at the time of the advance of the American troops in the Argonne, and previously on a lesser scale in the St. Mihiel Salient. The first proposition that confronted the Americans, of course, was to throw a line across "No Man's Land" in order to connect up with the abandoned German track. Prior to the opening of the St. Mihiel offensive a careful study had been made of the situation, and material of all sorts had been provided for connecting up the German lines at three points: From Flirey to Essey, from Bois Chenau to Woinville, and from Point au Metz to St. Baussant, the average distance being about five miles, including the approaches on both sides and the distance across "No Man's Land". Work was started simultaneously on all three lines on the morning of September

12th, 1918, but it was not until about October 1st that these lines were fit for train operation, in spite of ample troops and material having been provided beforehand. Mr. Hoyt.

This same condition existed in the Argonne, aggravated by a marked shortage of rails, ties, etc., as time and transportation had not been available for their concentration back of the lines. So great had been this delay that at the time the Armistice was signed the farthest point of light railway operation was about Buzancy, or approximately half way from Varennes to Sedan. Furthermore, this point marked about the end of the system of German light railway track abandoned by them in their retreat, and from here the Americans would have been compelled to build entirely new lines to supply the troops if the forces had been pushed ahead. This condition existed in spite of the fact that somewhat more than 6 000 men were employed on the light railways of the First Army at that time.

From this it can be readily seen that, although the light railways had proven their value in a "war of position", they proved totally inadequate in following up an extended advance, and the troops were forced to fall back on the road transportation for their supplies.

Reviewing the conditions as they existed on the St. Mihiel and Argonne fronts during the advance of the American forces in September, October, and November, 1918, it is the speaker's opinion that better results would have been obtained if every effort had been centered on pushing forward the standard gauge rail-heads, which at the time of the Armistice had reached Varennes, and improving the roads, so that the greatest possible volume of road transportation could have been used for the supply of the troops. This would have necessitated a careful study of the available roads and a well-trained body of Military Police to handle the traffic and avoid congestion. In order that these roads might be kept in the best possible shape, the men and ballast used on the light railways should have been diverted for this purpose, leaving the 60-cm. lines to handle the salvage collected from the battlefields, pushing forward their lines as conditions permitted.

W. B. Poland,* M. Am. Soc. C. E.—Illustrating the critical situation as to transportation at the front: In the early months of 1918 the speaker attended a conference between representatives of the American Expeditionary Forces and the British Army Transport Service, represented by Gen. Thornton, formerly of the Long Island Railroad, then in charge of transportation along the British front. Mr. Poland.

After explaining the terrible straits of the Allies, for cars and locomotives, Gen. Thornton said: "If the line stays where it is, we can probably get up our supplies and ammunition, but if the Boche ever retreats, God help us, we're lost!"

* New York City.

Mr. Pugh. MARSHALL R. PUGH,* M. AM. SOC. C. E. (by letter).†—The author has touched but briefly on a phase of light railway work about which he is well qualified to speak, namely, the light railways in the extreme forward areas, where conditions differed materially from those obtaining farther away from the trenches.

The light railways as operated by the American Expeditionary Forces may be divided into three zones:

(*a*) Near the rail-head, operated by steam locomotives.
(*b*) The forward area, operated by gasoline locomotives.
(*c*) Tram lines at the extreme front, using animal or man power.

Wherever the lines were far enough from the enemy to be reasonably safe from shelling, steam locomotives were used, as they were more powerful and could haul heavier trains. The gauge of track was 1 ft. 11$\frac{5}{8}$ in., and the over-all width of the steam locomotives was 6 ft. 5 in., consequently they needed a substantial track. Nearer the front, the light at night and the steam and smoke by day made them undesirable, so gasoline locomotives were used. Where their use was impracticable even at night, as well as on numerous spurs to batteries, mules and horses were used, or the ammunition and supplies were transferred to light cars pushed by men. Fig. 10 shows a light car transporting water on a spur reaching within a few yards of the front line trenches, and is typical of tram-line conditions at the extreme front.

The first, or (*a*) zone, approximates more nearly to an ordinary railroad, and has wooden ties, rock or gravel ballast, and comparatively light grades and curvature. The road is divided into blocks with a telephone train-despatching system. Where not subject to shelling, small huts were used by the despatchers, as shown in Fig. 11. These huts were made in sections hooked together and could be taken down in a few minutes, moved, and re-erected at another place with equal rapidity. In the forward zone semi-circular steel elephant huts were used to house the despatchers. These huts were protected by sand-bags as shown in Fig. 12, which is a view of the despatcher's hut in Broussey. This hut was at the terminus of the gasoline-operated section, beyond which animal traction was used. All operation was by night, and the curtain screen hung across the roadway was to hide it from enemy observation.

The road in exposed places was screened by camouflage, as shown in Fig. 13. At first, there was a great deal of hesitancy about building much in the open in forward areas, but experience showed that it is very difficult to hit such a narrow target unless it is directly enfiladed. Near Beaumont, a point called "Dead Man's Curve" was subjected to shelling for months, but comparatively infrequent repairs to the track were necessary. When a shell did hit the track, it was a simple matter to take out

* Wayne, Pa.

† Received by the Secretary, March 18th, 1920.

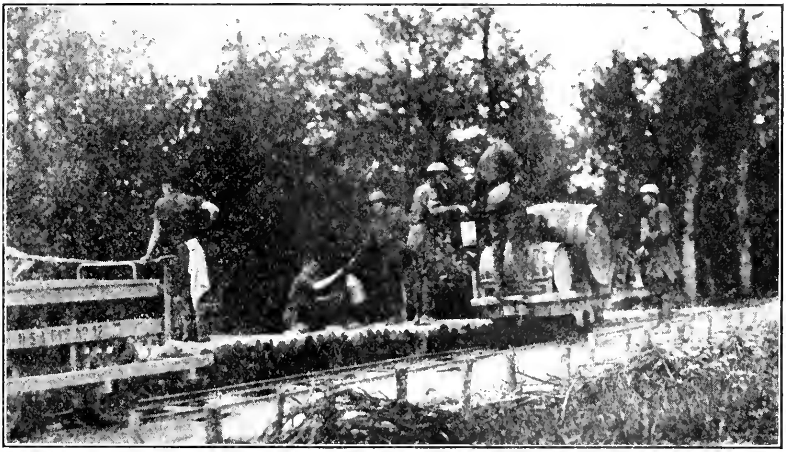


FIG. 10.—WATER CAR ON TRAM LINE.

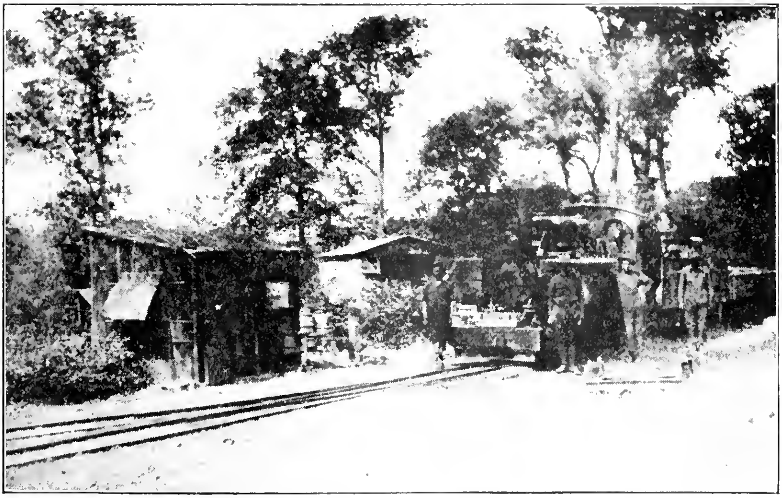


FIG. 11.—PORTABLE DESPATCHER'S HUT, LA REINE.

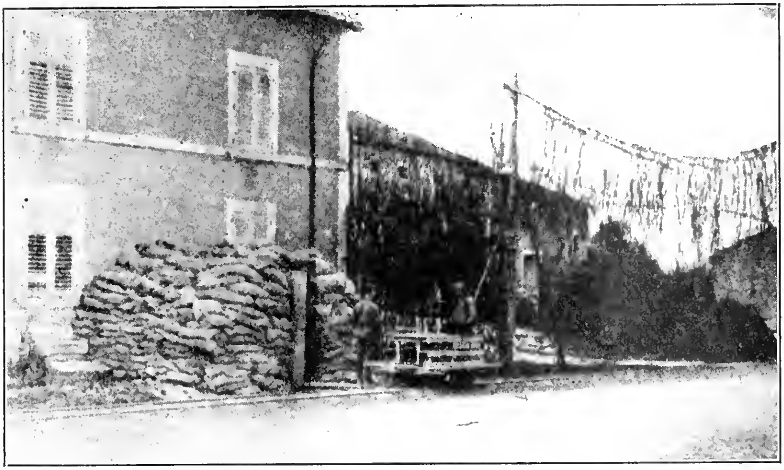


FIG. 12.—DESPATCHER'S HUT, BROUSSEY, SHOWING SAND-BAG PROTECTION.

FIG. 13.—CAMOUFLAGE AT THE FRONT.

the damaged section, or sections, as shown in Fig. 14, and replace them by new sections. Wrecking trains were stationed at intervals, on which were carried some full length (5-m.) sections of track and some half and quarter sections, ready to make a quick run to any damaged point and replace the track. The difficulty of hitting the track and the ease of repair makes it far more costly to destroy a light railway by shell fire than to restore it. It is about as impracticable to destroy such a railway by shell fire as it is to get rid of cooties in the same manner. This fact is their protection. Mr. Pugh.

There were two abandoned meter-gauge railways in the Toul Sector, and in places much work and ballast was saved by laying the light railway track in the center of the old meter gauge, as shown in Fig. 15. The dug-outs and huts shown are in the shelter of the old railroad cut just behind the trenches and are occupied by the troops holding that part of the line. As illustrating the amenities of life in this region, one of the writer's corps making a railroad location in "Shrapnel Valley" just to the right of this point, was hailed one day by an officer who said that the Boche had broken through and he wanted the survey party to help man the machine guns till reinforcements arrived. The survey was temporarily deferred.

Just south of this point the light railway left the meter gauge, which formerly crossed on the bridge shown in Fig. 16. Barbed wire entanglements are shown in the foreground, also one of the narrow-gauge "speeders". These little speeders were used by officers and men, repair gangs, and the like, for getting over the road, and were indispensable. Their usefulness would have been far greater, however, had they been adapted to the service they were called on to perform. There were two types. The one shown in Fig. 16 held six persons; it had one cylinder, was cranked by pushing it along the track and, when on a heavy grade, good track was absolutely essential, as it would stall if not moving rapidly. The smaller speeder, holding three persons, had two cylinders, was swifter and more easy riding, but stalled even more readily on grades and jumped the track on no provocation whatever. The writer preferred it to the other, but took many an unpleasant spill. Derailments were constant with each type, as they had no clutches, and although they would run well on a smooth track, they could not be operated slowly and were entirely unsuitable for conditions at the front. Several serious injuries and one death occurred from their use by the 21st Engineers. They should have had clutches, means of cranking, and have been geared so that they could run slowly on poor track. There is a good, light friction-drive speeder in the market.

The general instructions on location were to avoid heavy work, and Figs. 11, 13, 14, and 18 indicate the character of the great bulk of the line constructed. Where the track leaves the rail-head at Sorcy Yard, on the curve marked "To Cornieville" on Plate II, there was a ridge to

Mr. Pugh. be crossed, and as heavy traffic had to be handled, the writer put in the only heavy work in the line—a 17-ft. rock cut shown in Fig. 17. A French highway is carried by the bridge in the foreground. There was considerable criticism prior to the completion of this cut, but the writer heard of none after it was finished and operation showed the justification for it. In general, however, work of this character would be utterly misplaced in light railway lines. Ease and speed of construction are generally of paramount importance, and it is also necessary to know just how long it will take to construct a given line under prescribed conditions as to number of men available. The construction forces must be divided in such a manner that grading, track-laying, and ballasting will progress with equal rapidity, so that the line will be completed without any delay due to the track being held back by grading, or by ballast not keeping up with the track. Conditions varied materially, but a rough average of the lines in the forward part of the Toul-St. Mihiel Sector indicated that with approximately a 1-ft. cut or fill, the forces should be proportioned as follows:

Clearing	5	men.
Grading	60	"
Track-laying	10	"
Ballasting	25	"

Progress charts were prepared, and when the work was completed it was checked against the preliminary estimates, as shown in Table 2.

TABLE 2.—ESTIMATED AND ACTUAL PERCENTAGES OF WORK ON "K" LINE (RAULECOURT).

	Estimated percentage.	Man-days.	Actual percentage.
Clearing	4	69	5.11
Grading	60	751	55.59
Track laying	10	199	14.73
Ballasting	26	332	24.50

The Sorcy-Cornieville Line aggregated 2 344 man-days per mile, comparing in this respect with the Abainville Line cited by Col. Jonah. Each was what may be termed a trunk line. The Hamonville and Raulecourt Lines, on the contrary, were close to the front, with light grading and sectional track. The Hamonville Line averaged 1 024 man-days per mile and the Raulecourt Line 1 169 man-days per mile. The Abainville Line and the southern part of the Cornieville Line were laid with wooden ties. At the Cornieville end steel ties and sectional track were used, which afterward were replaced by wood. To avoid interruption to traffic during the change, the wooden ties were placed between the steel ones, and the new rail, bolted together in sections several

FIG. 14.—REPLACING TRACK DAMAGED BY SHELL FIRE.

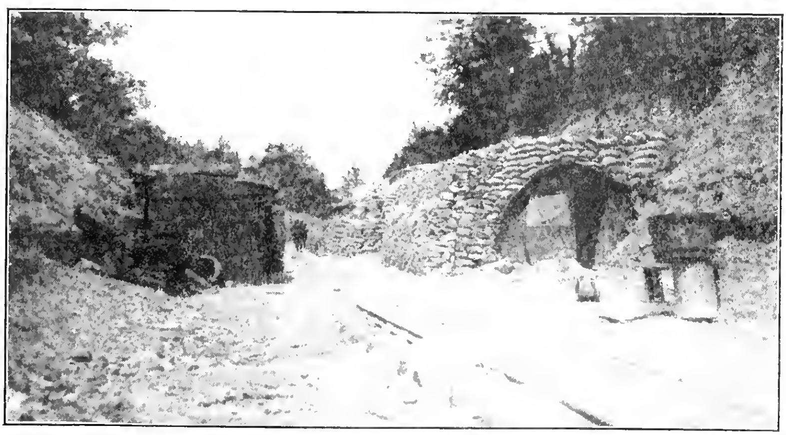


FIG. 15.—60-CM. TRACK LAID ON OLD METER GAUGE LINE.

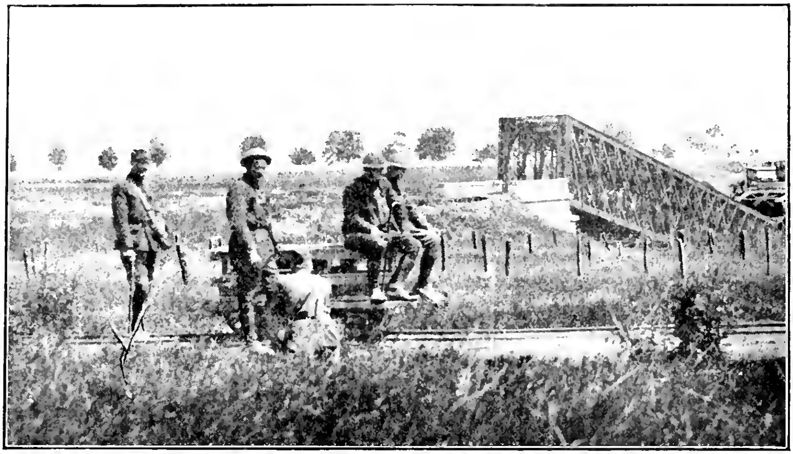


FIG. 16.—LIGHT RAILWAY "SPEEDER", ENTANGLEMENTS AND DESTROYED BRIDGE NEAR FLIREY.

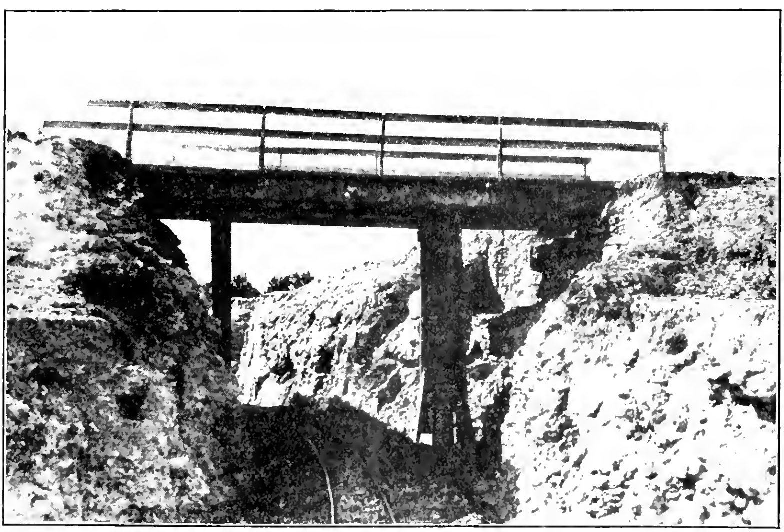


FIG. 17.—EXCEPTIONAL WORK ON LIGHT RAILWAY; 17-FT. ROCK CUT AT SORCY.

Mr. Pugh.

hundred feet long, was laid on either side of the sectional rail. After the passage of a train the sectional track was lifted out, thrown to one side, and the new rail quickly spiked to the wooden ties, only four bolted connections being necessary for the entire section. Fig. 18 shows this operation. The new rail is ready to be spiked into place as soon as the sectional track is lifted. In the foreground enough of the 25-lb. American rail on wooden ties is shown to indicate its superior alignment and solidity.

It will be noted that the lines at the extreme front averaged only about half as many man-days per mile for construction as those farther back. They had few bridges and all the work was light. On the contrary, given an equal amount of traffic, the maintenance on these lines was greater, and wooden ties held up much better than steel ties.

What lesson experience in the World War teaches as to the defects that developed in the light railways, and the remedy, is a question of utmost importance.

Paul McGeehan, M. Am. Soc. C. E., in an article entitled "Notes on Army's Light-Railway Practice in France",* has put his finger on what the writer considers the lesson to be profited by if light railways are to be made the success which their importance demands. Capt. McGeehan says, "The number of derailments was almost a scandal. On one classic occasion at Tincourt, on the British front, all of the steam locomotives in the service were on the ground at the same time. Derailments were so numerous and the cause of so much loss of time that orders had to be issued to reduce speed to not more than eight miles an hour."

The first and most obvious thing to which consideration should be given is the roadbed. Ballast is by all odds the most serious problem in light railway construction. In Table 2 it will be noted that 24½% of the labor, on that particular branch, was used on ballasting, but this does not begin to cover what is involved in that part of the construction. The quantity of ballast needed and the long hauls frequently necessary before it can be placed, choke the railroad with ballast trains. In the week ending April 19th, 1918, of 4 674 tons hauled on the light railway, 1 290 tons consisted of ballast. For the week ending August 31st, 1918, the total hauled was 19 885 tons, of which 2 717 tons were ballast. The following week the figures were 34 942 tons total, 7 954 tons of which were ballast. In general, the ballast varied between one-tenth and one-quarter of the tonnage moved. Capt. McGeehan calls attention to one instance where ballast had to be fed continuously into certain lines in order to keep ration trains running. "Ballast, even, had to be put under this track to keep the ballast trains themselves running." He agrees with Col. Jonah in considering wooden ties preferable, because surface and line are more readily kept, and steel ties cut into the ballast.

* *Engineering News-Record*, October 2d, 1919.

Mr. Pugh. Their contention is not open to dispute, and when it can be done the writer would advocate their utilization, but he feels that in the forward areas the superior speed with which sectional track can be laid, especially at night, the lessened demand for skilled labor, and the avoidance of noise due to spiking, make the bolted sections with steel ties vastly preferable.

Much of the sectional track used by the American forces was French Decauville track with 16-lb. rails. This is too light for main track, and the head of the rail is too narrow to give the drivers proper adhesion. The American 20-lb. and 25-lb. rails were superior in every way. Personally, the writer prefers the 20-lb. rail, as it seemed to be quite as satisfactory and is lighter to handle. It is a mistake to have both. The difference in appearance between the 20-lb. and 25-lb. sections is negligible, and in one instance led to disastrous results. A start was made to lay several miles of sectional track, and after quite a stretch was down, the sections failed to fit. It was then discovered that the erection shop had forwarded to the front sections having one 20-lb. and one 25-lb. rail to each section. It was not noticed as long as the sections happened to have all the 25-lb. rail on the same side. When, however, a 20-lb. rail came to match up against a 25-lb. rail, trouble began, and a gentle critique of the erection shop by the track-layers ensued.

The American standard sectional track, 5 m. (16 ft. 5 in.) long, had eight ties, with a total tie area in bearing of 13.76 sq. ft. per section. The German sections were not all alike, but in general had ten ties to the section. One excellent type had a total bearing area of 23.2 sq. ft., or 176% of the area of the American section. The American 20-lb. rail section weighs 406.4 lb. The German section with American 20-lb. rail would weigh 549 lb. Although heavier to handle, it would not be objectionable. Furthermore, the German ties are 4 ft. long, 5 in. longer than American ties, giving somewhat superior stability. Of most importance, however, is their width which is 7 in. as against $5\frac{1}{2}$ in. for American ties. The Second Progress Report* of the Special Committee to Report on Stresses in Railroad Track throws an interesting light on the relative supporting capacities of these two widths of tie. It shows that the supporting capacity is greatly increased by increase of width. Table 18 of that report indicates that "with jarring" the German tie would support a load of approximately 160% of that of the American tie. Since there are 25% more ties to a section, the superiority of the German section on a poor soil is apparent.

The writer would advocate the continued use of sectional track at the extreme front, or wherever speed in construction is essential, using on soft ground a mat of brush, leaves, or the like, when obtainable, before placing the ballast. Where wood is available, he has found great benefit to result from inserting between the steel ties on bad ground

* *Proceedings*, Am. Soc. C. E., February, 1920, p. 133.

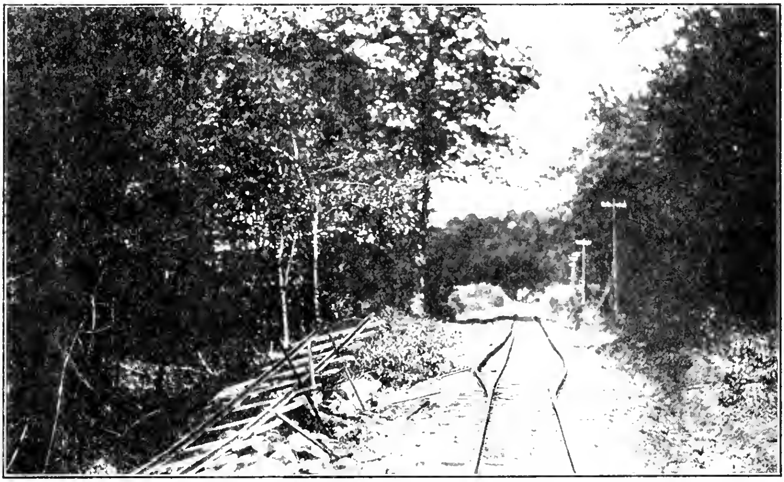


FIG. 18.—REPLACING SECTIONAL TRACK BY RAIL WITH WOODEN TIES.

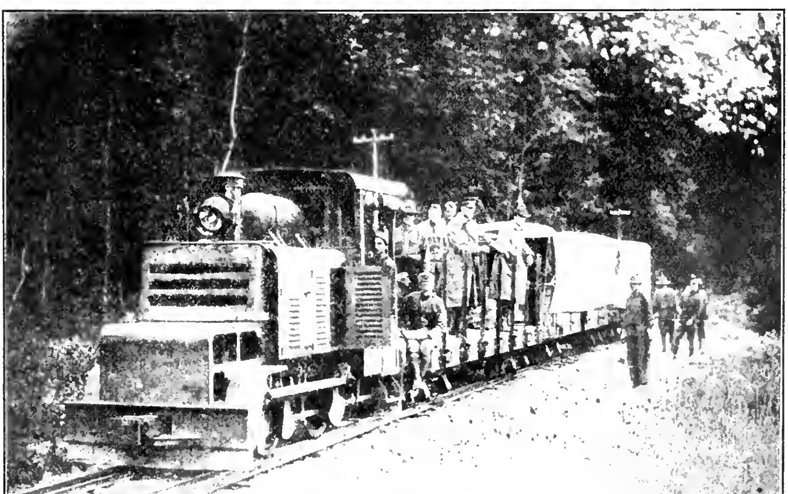


FIG. 19.—LIGHT RAILWAY GASOLINE TRACTOR AND FLAT CARS.

either wooden ties, planks, or boughs of trees, to give added bearing power and stability. Mr. Pugh.

As to gauge, where an enemy's lines have the 60-cm. gauge, as was the case in France, it is undoubtedly preferable to adopt the same, so that his lines may be utilized in an advance. Otherwise a 30-in. gauge would be preferable. Neither the rolling stock nor the track would weigh any more, and the tendency to derailment would be less.

Practically all the articles which the writer has read on the subject regard the great part of the troubles in light railways as arising from poor roadbed. Desirable as some track changes may be, they are of minor importance, in the writer's judgment. It must be borne in mind that under battle conditions the roadbed must and will be poor. It is vitally necessary to get cars and engines that will run on a poor roadbed. This has been the writer's contention from the start. American rolling stock was based on the idea of a miniature standard-gauge railway. It should be based on that of a contractor's rough-and-ready construction railway. An interesting side light is thrown on this by a remark on page 218 of the "Historical Report of the Chief Engineer * * * American Expeditionary Forces," where it is stated: "It was found that the lines of the German system contained many sharp curves and heavy grades, which called for reduction before American equipment could be successfully operated." Lieut. Harvey W. Bell, of New York City, formerly of the 21st Engineers, A. E. F., a mechanical engineer of great experience in industrial railways prior to the war, as well as in operation of light railways in France, writes:

"I took six trains of about seven cars each, using steam power, from Sorcy to the Argonne. We passed near Mt. Sec and ran near the new front over German track and had some pretty exciting times. Our locomotives made so much noise and showed so much light that they must have been easily located. To add to our troubles both engines and cars seemed always to leave the track as soon as shells began to land near us. One night in the Argonne our steam engine turned over on its side on a bad curve, blocking the main line. We worked until midnight getting it up again, and no sooner were we prepared to start than it turned over on its other side and we didn't get it up till morning. I could tell you a hundred stories of a similar nature with our equipment, yet I never saw a French engine or gasoline locomotive off the rail."

The American gondola and flat cars were 24 ft. 1¼ in. long over couplers, and 15 ft. center to center of trucks. The weight of the gondola was 9 000 lb. and of the flat car 8 000 lb. Lieut. Otis T. Gregg, of the 21st Engineers, also a man of wide experience in industrial railways, suggests a four-wheel car which could be made of one-half the capacity and one-third the weight and which six men could lift on the track. The little four-wheel, V, dump cars, 6 ft. 9 in. long over couplers, kept the rails on rough track and would go around curves

Mr. Pugh. which the other cars would not begin to take. Fig. 21 shows how heavy loads can be moved by very simple rolling stock.

The steam locomotives (Fig. 11) were too high, had a bad spring suspension, and only 68% of the weight of the locomotives was carried on the drivers. The rear drivers would pull off the rail on the inside of the curve when hauling a heavy train over sharp curves, because the over-all length was too great in proportion to the wheel base.

In locations made by the 21st Engineers compensation for curvature on grades was made at the rate of 0.02% per degree of curve. Nevertheless, with the long cars operated by the Americans, curves offered much greater resistance to traffic than grades.

The writer's regiment was fortunate in having several mechanical experts of great ability, and they were in entire agreement with him—he is not a mechanical engineer—as to the desirability of a different type of rolling stock. Lieut. Alfred D. Chandler, Jr., now representative of the Baldwin Locomotive Works in South America, was most insistent on the need for a revision in the design of American engines. A double-truck gasoline locomotive with all the weight on the drivers, a motor of about 75 h. p., and a four-speed transmission, to replace both the steam and the gasoline locomotives would be, in the opinion of those better qualified than the writer to pass judgment, a great change for the better. In France, conditions occurred in which the locomotives had to remain miles away from proper supplies of coal and water and pit tracks. Gasoline locomotives could carry supplies of all kinds sufficient for four days' hard work.

In stressing the question of rolling stock, it is possible that the writer's meaning may be misconstrued. It is not his intention to advocate poor track. Make it the best that is possible, but when conditions compel that "best" to be poor, have cars and engines which will run on the worst of it, and which can readily be re-railed.

The light railway is not adapted and should not be used for long hauls, which can be far better taken care of by the standard gauge. It is not practicable to destroy it by shell fire, so that it should be used where the standard gauge cannot be operated, with necessary extensions to the rear to reach properly located shops and to enable the withdrawal of equipment in event of an enemy advance, these extensions to be located and built in accordance with the best principles of standard-gauge practice.

On page 82,* Col. Jonah has clearly and succinctly stated the primary reasons for the development of light railways. Some concrete examples of what the light railway does may be of interest. Maj. G. Boyer, of the 4th Canadian Division, in a report to Sir Henry Jacob, gives an idea of the great saving in work effected by them. He says:

* *Proceedings*, Am. Soc. C. E., January, 1920.

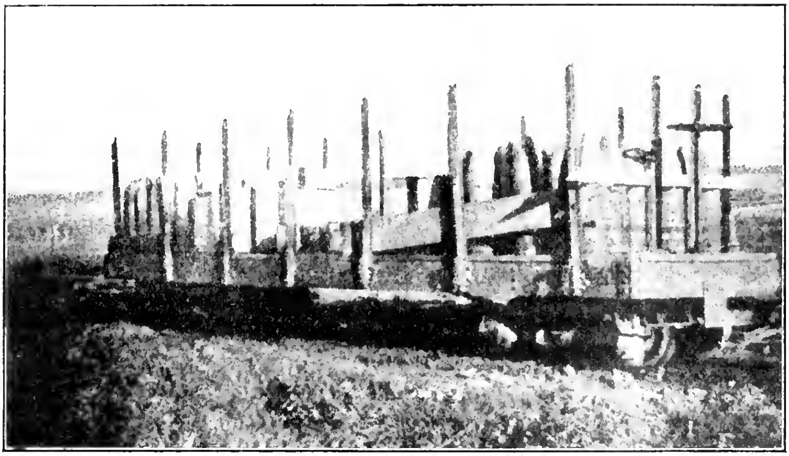


FIG. 20.—FLAT CAR LOADED WITH AMMUNITION.

FIG. 21.—HOWITZER ON THE LIGHT RAILWAY.

"Before the tram lines were organized and constructed one horse and one man brought to his battery eight 18-lb. shells, therefore to deliver 16 000 rounds it took 2 000 horses and 2 000 men; by the tram lines, taking as an average a hundred rounds per truck, it would take 160 horses or mules and 184 men; saving and allowing to rest 1 816 men and 1 840 horses or mules." Mr. Pugh.

Light railways are also of the greatest aid in troop movements, saving tiresome marches (generally at night) and relieving the already congested highways. An extract from a citation to the 21st Engineers by the Commanding General of the 82d Division illustrates this point very clearly. He says, in part:

"The light railway is a great saving on trucks and gasoline; also a great saving on the men, who were saved physical exertion moving about and were able to apply the exertion in other more important work. It also made it possible for the men to move quickly during the reliefs, where to camp men in unusual stations or move them about in daylight would attract enemy fire and suspicion. Some 20 000 troops were moved in a recent relief, much to the benefit of the troops."

The writer would like to take this opportunity of expressing his appreciation of the great help which the author's keen observation and trained judgment was to him on the location and construction of the light railways. He is deeply indebted to Col. Jonah for his criticisms and suggestions.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

EXPERIMENTS ON THE FLOW OF WATER THROUGH CONTRACTIONS IN AN OPEN CHANNEL

Discussion*

By Messrs. William T. Lyle, D. C. Henny, Karl R. Kennison, and R. D. Goodrich.

William T. Lyle,† Assoc. M. Am. Soc. C. E. (by letter).‡—The conclusions drawn from these carefully prepared experiments are characterized by the cogency of their logic. The author regrets the fact that owing to the war his examination was not carried further. It is to be hoped that so profitable an undertaking may be continued, not only in the interest of hydraulic science, but also for the practical benefit of the profession. The author very properly calls attention to the folly of using hydraulic formulas beyond the limit of their application. A formula must be modified or changed whenever a new condition arises in the flow. The danger here involved has been forcibly brought home in the use of run-off formulas; but there are many other examples as well, and many a hidden rock on which professional reputations have been damaged. Mr. Lyle.

Any device for contracting the cross-section of a jet or stream of water constitutes a measuring device. Thus there are orifices, weirs, Venturi meters and contracted open channels. The underlying principle in them all is the hydraulic expression of the law of the conservation of energy, namely, Bernonilli's theorem—pressure head plus velocity head plus friction head is a constant.

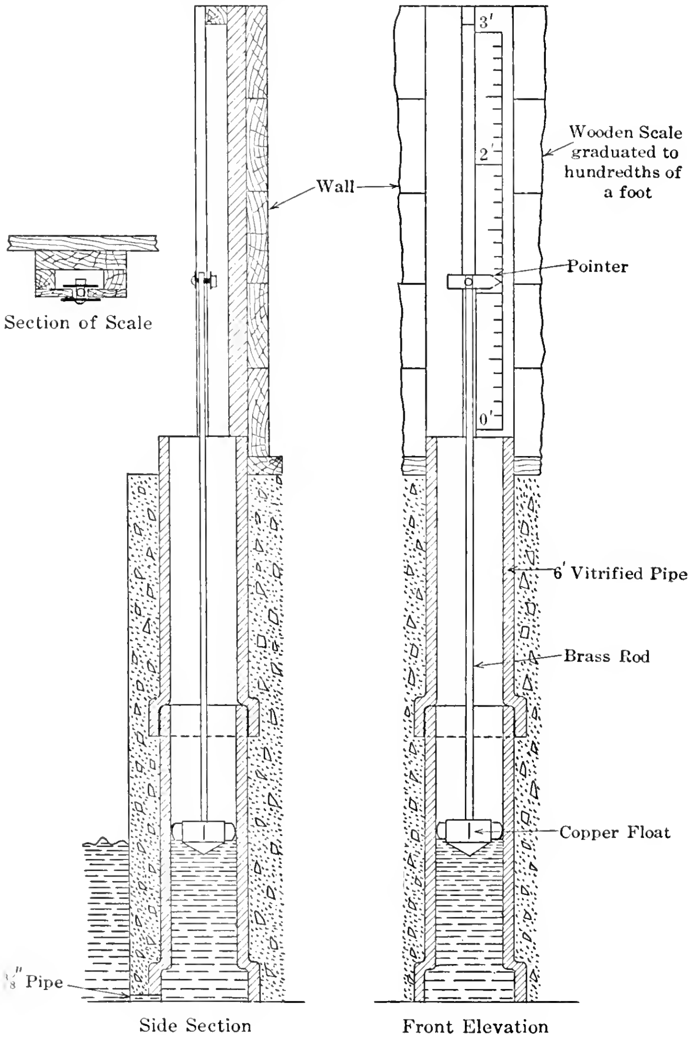
Some years ago, the writer designed a stilling box for use in volumetric tank measurements and weir determinations. It consisted

* This discussion (of the paper by E. W. Lane, Assoc. M. Am. Soc. C. E., published in October-November-December, 1919, *Proceedings*, but not presented at any meeting) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Houston, Tex.

‡ Received by the Secretary, March 5th, 1920.

Mr. Lyle. of a copper float, convex on the lower side, with a brass stem to hold an index which passed up and down through a slot on the recording scale. All graduations were on wood which is believed to be a small improve-



FLOAT GAUGE

FIG. 21.

ment on the steel tape referred to in the paper because of the fact that wood does not corrode. The float moved up and down through a riser of sewer pipe, with a small hole for the entrance of water at the bottom, as shown in Fig. 21.

In order to guard against any possibility of binding it was the practice to tap the index lightly with the finger before taking a reading. This float gauge gave good results and is better than a hook-gauge, where rapidity and elimination of surge are necessary. Mr. Lyle.

In discussing Formula (4), the author says: "Part (*b*) of the discharge, according to the Weisbach theory, is exactly equal to the total discharge according to the d'Aubuisson theory." This is true providing the coefficients are the same. The separate coefficients appear in Formula (14). The writer questions the strict applicability of Formula (12), which applies to orifice flow. This same equation appears in modified form again as Formula (18). The distinction made between stream line and turbulent flow is not well taken. The stream-line theory is now obsolescent, if not obsolete.

The author very properly calls attention to the great advantage of the expanding flume over the weir for water measurement, the flume being free from clogging by floating matter, free from silt deposits, and requiring much less loss of head.

D. C. HENNY,* M. AM. SOC. C. E. (by letter).†—Under the head of "New Water Measuring Devices", the author refers to the Venturi flume suggested by Mr. V. M. Cone.‡ A somewhat different and equally simple device using the Venturi principle was suggested by the writer in 1915, for the purpose of measuring flow in irrigation laterals. It consists of an ordinary rating flume with parallel sides, the only addition being a thin, galvanized steel plate fastened to the sides, which depresses the water surface so as to contract the flow area to a throat, as shown by Fig. 22. Mr. Henny.

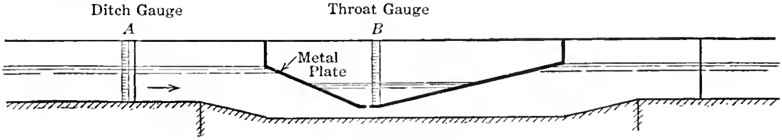


FIG. 22.

For ordinary irrigation heads of from 3 to 6 sec-ft., the throat is 4 in. high and 2 ft. wide, the throat velocity varying from 4.5 to 9 ft., with corresponding velocity heads of 0.31 to 1.26 ft. Two vertical staff gauges, *A* and *B*, are read, the upper one placed in the ditch above the wings of the flume, the lower one in the head-water basin above the metal plate which communicates through small holes in the throat with the flowing water.

For a flow varying from 3 to 6 ft., the velocity in the approach ditch may range from 1 to 1.5 ft. Allowance is made in the formula used for the mean velocity head of approach.

* Portland, Ore.

† Received by the Secretary, March 25th, 1920.

‡ *Journal of Agricultural Research*, Vol. IX, No. 4, April 23d, 1917.

Mr. Henny. Experiments made on three reclamation projects with flumes similar to that shown in Fig. 23, indicate that, in the formula,

$$V \text{ (Throat Velocity)} = C \sqrt{2\,g\,(H + h)},$$

in which H is the difference in gauge readings and h the mean velocity head of approach, the value of C increased with H. For the dimensions of flumes used in the experiments, the formula becomes:

$$V = (0.85 + 0.05\,H) \sqrt{2\,g\,(H + h)}$$

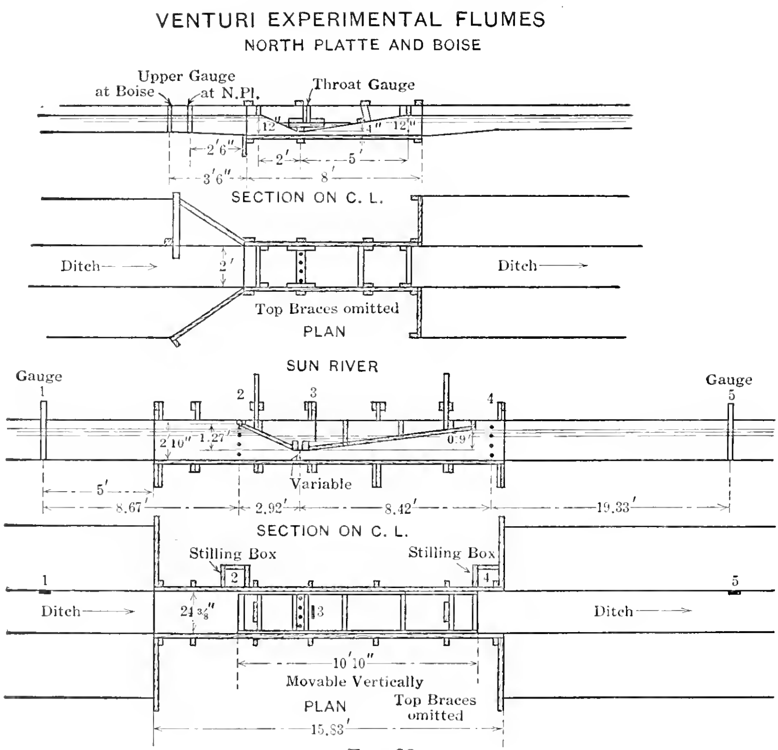


Fig. 23.

The flow thus determined in 39 experiments in which the throat velocity was 3 ft., or more, was compared with the flow measured by standard Cipolletti weirs with the following results (see Fig. 24):

35 measurements show error of less than 3 per cent.
3 " " " " " " 5 " "
1 " " " " " " 7 " "

These results appear to be quite satisfactory, considering that the weirs themselves are subject to error and that they represent three

devices built and tested at widely separated points and by different experimenters. Mr. Henny.

The device is cheap, and the gauges can be easily read by an ordinary ditch rider. There is little danger of silting and the loss of head where flaring wings are used; both down stream and up stream, can be held

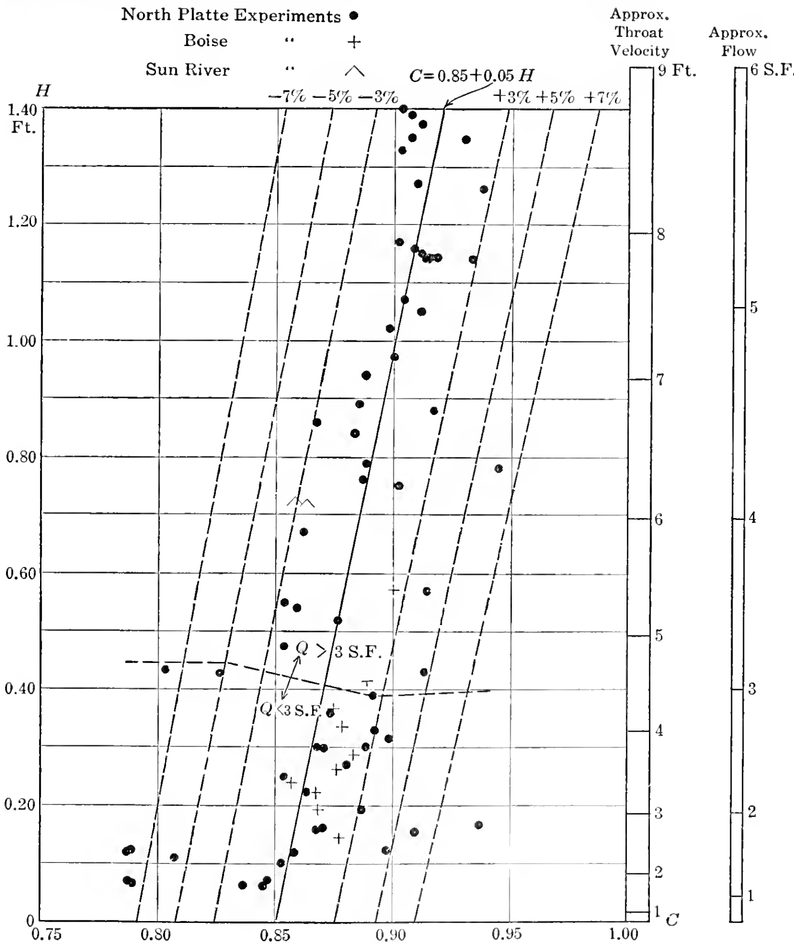


FIG. 24.

down to less than 20% of the velocity head at the throat, or for the dimensions and maximum flow in question to less than 3 in. The accuracy is not seriously affected by the usual range in variation of back-water.

Under certain conditions this form of Venturi flume is likely to be more accurate than the weir, partly because a small error in gauge

Mr. Henny. reading has a smaller effect. It was intended, however, especially for cases where the available head is small or where the water carries considerable silt.

Mr. Kennison. KARL R. KENNISON,* ASSOC. M. AM. SOC. C. E. (by letter).†—The writer has read Mr. Lane's valuable contribution to the literature on the subject of high-velocity flow in open channels, and has been particularly interested in the experiments in which the channel was given a smooth rounded entrance, producing a fairly smooth stable flow through it, with the internal pressure conditions in such channel not upset by a sharp-cornered entrance.

One point which the writer wishes to make in this connection is that the quantity of discharge through a channel or conduit of this type may be governed by other conditions than the depth of water down stream, that each condition of flow must be studied by itself to determine just what it is that controls the quantity of flow, and that it is usually a simple matter to make this computation with remarkable precision, even when high-velocity flow and the hydraulic jump are involved.

The conclusion to be drawn from the experiments is a justification of the d'Aubuisson formula, in other words, the Bernouilli theorem. Everything in the experiments confirms this theorem and, consequently, justifies the computation of maximum discharge as the discharge at a depth equal to two-thirds the total net head, or twice the velocity head. Accordingly, if the down-stream head on the controlling section is less than two-thirds the total net head, it is too low to have any effect on the quantity discharged (through a channel or conduit long enough to contain a reasonably uniform flow). It is also true that the down-stream head can be quite a little greater than this two-thirds depth without materially decreasing the discharge. This characteristic of the water surface near the two-thirds depth has a tendency to create surface waves.

One point which should be borne in mind is that the undulating surface profile does not represent the pressure head on the water beneath the surface, as one might be led to expect from the author's computations and plotted results. The vertical height based on this undulating surface which he has marked "loss of head", and which appears to increase and decrease through the length of the channel, is not the actual loss of head. The actual loss continually increases and can never be recovered. The author's profile would have been clearer, if this loss of head had been plotted vertically down from the "elevation of head water", in such a way as to show the net available head continually decreasing. Then the critical two-thirds depth instead of being

* New Orleans, La.

† Received by the Secretary, March 25th, 1920.

plotted as two-thirds of the total original head, should have been plotted as two-thirds of the net head after subtracting this loss. This then would have shown a more remarkable coincidence between the actual depth in the channel and the theoretical two-thirds depth for a maximum unobstructed flow. Mr. Kennison.

To bring out this point more clearly, the writer has taken all those experiments in which the rounded entrance was used, has used a constant coefficient for this entrance of a little less than 0.92, which is the coefficient apparently indicated by the experiments, and has computed the discharge by analyzing each case separately, both with and without the expanding flume, disregarding entirely the down-stream water level when it is lower than the critical two-thirds depth. The computed results (Table 11), compare remarkably well with the measured discharge, undoubtedly well within the precision of the measurement of the discharge.

TABLE 11.—Flumes with Rounded Entrance.
Channel, 1 Foot Wide; Radius of Entrance Sides, 6 Inches.

See Author's Tables 4, 6, 7, 8, 9, 10.*	Short Flume.			Expanding Flume.				
Run number.	1†	2†	3	1	2	3	4	5
Up-stream head, in feet	1.41	1.31	1.16	1.05	1.08	1.11	1.18	1.30
Drop to pool	0.608‡	0.453	0.362	0.33	0.159	0.119	0.093	0.067
Down-stream water level	0.802	0.857	0.798	0.72	0.921	0.991	1.087	1.233
Effective down-stream head‖	0.802	*0.857*	*0.798*	§	*0.68*	*0.82*	*0.96*	*1.14*
Loss at entrance¶	0.084	0.072	0.058	0.062	0.064	0.05	0.04	0.03
Net up-stream head	1.326	1.238	1.102	0.988	1.016	1.06	1.14	1.27
Two-thirds of up-stream head**	*0.884*	0.825	0.735	*0.659*	*0.678*	0.71	0.76	0.85
Velocity head	0.442	0.381	0.304	0.329	0.338	0.24	0.18	0.13
Computed discharge, in cubic feet per second	4.72	4.25	3.53	3.03	3.17	3.2	3.3	3.3
Measured discharge	4.735	4.267	3.537	3.0	3.12	3.2	3.2	3.1

* *Proceedings*, Am. Soc. C. E., October–November–December, 1919, pp. 732-734.

† The numbers of these runs appear to be interchanged in Table 4.

‡ 0.508 in Table 4 is apparently an error.

‖ Before velocity head is recovered (with, say, 20% loss) in expansion to 3 ft. width.

§ Too low possibly to affect the discharge; hydraulic jump must occur.

¶ Velocity head in flume, 19%, equivalent to discharge coefficient of a little less than 0.92.

** Use this depth if greater than effective down-stream head.

R. D. Goodrich,* M. Am. Soc. C. E. (by letter).†—This paper is believed to be a most valuable contribution to the literature of hydraulic investigations and is certainly one of great interest to all engineers dealing with problems of river training and regulation, as well as to those interested in irrigation and power development. Mr. Goodrich.

* Tientsin, China.

† Received by the Secretary, April 1st, 1920.

Mr. Goodrich.

The complete description of the plant and methods used, with the illustrations, give confidence in the accuracy of the tabulated data and the results shown. The Cippoletti weir is not usually considered to be as accurate a measuring device as the rectangular weir with suppressed contractions. However, in this case where special experimental coefficients are used, there is little doubt as to the reliability of the measurements. The author's descriptions of, and comments on, the float gauges are of considerable importance, and it would also be interesting to know what led to the selection of the particular curve used for the sides of the expanding flume.

The experiments show conclusively that the coefficients in the two formulas investigated are far from constant. Although these coefficients vary with the nature of the entrance to the contraction, it is clearly shown that this variation is some function of the effective head and depth of the contraction and also in one case of the width. It is possible that the coefficients for rounded or other forms of entrance vary with the width, as well as those for the sharp edged contractions. The author's results on the two different widths of the sharp crested weir agree in this regard with the coefficients recommended by Mr. W. G. Beigh from his observations and measurements made in India, which approach unity as the width of the contraction increases.

While the author has treated this variation as linear and while Fig. 10 would indicate a straight line law for the sharp edged contraction, it does not follow that it would be so in all cases; C might be expressed by a relation of the form:

$$C = a + b\left(\frac{H_3}{D_3}\right)^n$$

in which the law becomes linear when $n = 1$, as for the sharp edged contraction. The writer found that with $n = 2$, a single equation could be found to express the probable variation in the d'Aubuisson coefficient for the round edged contraction, very nearly if not quite as well as the two equations given by the author. To do this, the writer subdivided the points shown by the circles in Fig. 7 into seven groups. The centers of gravity of these groups were then found graphically and their co-ordinates tabulated. The coefficients were then plotted against the squares of ratios, $\frac{H_3}{D_3}$.

It was found that a straight line passes practically through all except the lowest of these points. An equation could be written giving a reversal in the direction of curvature so as to make the curve pass through the center of this lower group and near the lowest isolated point by introducing a term in the form $C\left(\frac{H_3}{D_3}\right)^n$, but there are not

enough experiments with very small differences in depth to warrant this. The resulting equation is : Mr. Goodrich.

$$C = 0.877 + 0.32 \left(\frac{H_3}{D_3}\right)^2.$$

This, however, is probably not the correct expression for the complete law of the variation in C, which should approach unity instead of a quantity less than unity, for very small values of $\frac{H_3}{D_3}$. For as H_3 decreases it approaches the value of the velocity head as its limit. With any given value for Q, H_3 decreases with increase in A, which has the area of the channel of approach as its limit. In order that the value of Q may remain constant as H and A both approach their limits, it is necessary that C approach unity as its limit. It seems probable, therefore, that the variation of C is only approximately linear even for sharp edged contractions. In other words, the author's investigations, by demonstrating the variation of C, also demonstrate that neither of the formulas discussed represents the true law for the discharge of contracted sections.

The above simply illustrates another method of analyzing the results obtained and is not intended as a criticism of the author's investigation. In fact, he brings out several characteristics in the formulas which might have been overlooked if he had used the method mentioned.

In discussing the sharp edged contraction, the author shows a very interesting relation between the d'Aubuisson and Weisbach formulas. In this connection the writer wishes to call attention to the statement made at the bottom of page 742,* that all the particles below the tail-water level have the same velocity. This assumption is used in the development of the Weisbach formula, but it does not agree with observations of velocities in open channels either above, below, or at gate openings and contracted sections.

The tendency of velocities in a vertical section of a stream to vary as the ordinates to a curve of more or less parabolic or elliptical form is too well known to be discussed here. It might be noted, however, that the rate of change of velocity is especially rapid near the bottom. The writer has measured velocities with a current meter above an open sluice-gate which showed a maximum velocity of approach of approximately twice the average, located considerably below mid-depth. The vertical velocity curve when plotted looked like an ordinary velocity curve inverted. All the observations taken at the several sections made showed the same conditions, and such "under tows" have been frequently observed. It is suggested that the words "theoretical velocity" would have given a more accurate statement for the author's purpose.

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* *Proceedings*, Am. Soc. C. E., October-November-December, 1919.

Mr. Goodrich. The author calls attention to the fact that the coefficients for the discharge above and below the level of the tail-water might be different, instead of being assumed the same as in the ordinary Weisbach formula, and further that the coefficient for the discharge below the level of the tail-water is the larger in the case of contracted sections, while for submerged weirs the larger coefficient applies to the section above the tail-water level. That this difference is due, at least in part, to the effects of contractions on the sides and surface, as explained by the author, is probably true. It may also be true that the depth of the thread of maximum velocity may influence these coefficients. It is certainly true that the maximum velocity and, therefore, the maximum discharge per unit depth is nearer the surface above a weir, than it is above a submerged gate; and the discharge through a contracted section is very similar to that through a particularly submerged gate.

The high values of the coefficients for the discharge through both the short and the expanding flume are very noticeable and lead one to think that the coefficients used in practise are frequently too small. The author's discussion of the experiments on these flumes is most interesting, and his theories appear to be most reasonable and logical. They agree with some of the writer's observations and offer explanations for various phenomena for the first time, so far as the writer is aware. A case in point is discussed in Appendix II.

The writer has not devoted much study to the phenomena of flow through flumes and therefore is unable to discuss that part of the paper as he would wish. The author's paper is one to be highly commended and it is sincerely hoped that he will soon be able to continue and enlarge upon his investigations, which have added materially to the knowledge of the undeveloped science of hydraulics.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

HENRY WILSON HODGE, M. Am. Soc. C. E.*

DIED DECEMBER 21ST, 1919.

When a man passes into the next life, leaving behind him a record of high accomplishment, the World seeks for the causes that lifted him above the general level of his fellows and in so doing gives first place to those influences that play so large a part in the moulding of man's character and in the shaping of his destiny—heritage and family tradition, early training and environment, education, and the associations of later years.

In the life of Henry Wilson Hodge the effect of these influences was manifest to a remarkable degree, in cultivating the qualities that won for him lasting fame, not only as a brilliant engineer, but in an equal degree as a patriotic citizen, a loyal friend, and a fearless man of broad humanities and lofty ideals to which he was ever true.

Henry Wilson Hodge was born in Washington, D. C., on April 14th, 1865—the day made memorable by the assassination of President Lincoln—of a long line of American ancestry reaching back to early Colonial times.

His father, John Ledyard Hodge, a great-grandson of the first of the line in America, who came from Ireland about 1745, was born in Philadelphia, Pa., was graduated from Princeton, and removed to Washington at the time that his father, William Ledyard Hodge, was made Assistant Secretary of the Treasury during the administration of President Fillmore. The paternal grandmother of Col. Hodge was Sarah Bayard, of Philadelphia, whose grandfather, John Bayard, was a leading man in that city and as Colonel of a Philadelphia regiment during the Revolutionary War served in many actions and was personally complimented by Gen. Washington for his gallantry at the Battle of Princeton. This John Bayard was a great-grandson of Peter Bayard, who came to this country in 1647 with his uncle, Peter Stuyvesant, the last Dutch Governor of New Amsterdam.

The mother of Col. Hodge was Susan Savage Wilson, a daughter of Henry Parke Custis Wilson, of Virginia, and a sister of the eminent surgeon of that name in Baltimore, Md. This family, which was of Scotch-Irish extraction, settled in America in 1700 and was instru-

* Memoir prepared by the following committee: W. J. Wilgus, Frederic A. Molitor, Howard C. Baird, and Robert Giles, Members, Am. Soc. C. E.

mental in founding the first Presbyterian Church in this country at Rehoboth, Md. Mrs. Hodge was a deeply religious woman of noble character, and her son often remarked to his friends that, raised as he was under Spartan conditions with no surplus of worldly possessions, it was to her teachings and example that he owed the best in his character.

In fact, it is hard to imagine how Mr. Hodge could have been otherwise than a man of high principle, with such fine traditions, early training, and environment.

Educated at Young's Private School in Washington, his health, always delicate as a child, broke under the strain of untiring study, and at the age of fifteen he joined a surveying party on the Chesapeake and Ohio Railroad in the mountains of West Virginia, and carried a chain for nearly two years. The experiences of this rough outdoor life not only built up his constitution, but they awakened in him the ambition to become an engineer. Acting on this thought he borrowed the necessary money through the kindness of a relative, and, in 1882, entered Rensselaer Polytechnic Institute, from which he was graduated in 1885.

Now fairly launched in his life's work, Mr. Hodge entered the service of the Phœnix Bridge Company, with which for six years, under the direction of its Chief Engineer, the late A. Bonzano, M. Am. Soc. C. E., he was successively Draftsman and Computer, Assistant Engineer and Resident Engineer, gaining through practical experience the broad foundation on which was reared his future success. Among the structures with the design of which he was connected during this period was the Huntington Bridge at Cincinnati, Ohio. He also had much to do with the planning and erection of the Pecos Valley Viaduct of the Southern Pacific Railway.

In 1891 came an important change in his fortunes when he accepted the position as Chief Engineer of the Union Iron Works, at New York City, in which city he spent the remainder of his life.

About this time Mr. Hodge joined the University Place Presbyterian Church and shortly after became an Elder and, later, one of its Trustees, giving freely of his time and substance to a cause which was always dear to him. For nearly thirty years, he was Superintendent of the Sunday-school of this Church, which he attended with unfailing regularity and where he exerted a great influence over hundreds of young people.

Soon after coming to New York City he had joined the Seventh Regiment of the National Guard. A stranger in the city, he found his service in Company K a real pleasure, and the friendships which he made there were among the warmest of his life. He always regarded his old regiment with genuine affection.

An important step in his life came in 1893 when his employment with the Union Iron Works was terminated, and he ventured into the field of the independent consulting engineer. For the ensuing two years Mr. Hodge did much important work, one instance of which was the preparation of standard plans of bridges, of lengths ranging from 10 up to 200 ft., for the 900-mile extensions of the Choctaw, Oklahoma and Gulf Railroad, of which Frederic Molitor, M. Am. Soc. C. E., was then Chief Engineer.

In 1895 he entered the employ of the late Alfred P. Boller, M. Am. Soc. C. E., with whom four years later he entered into partnership under the firm name of Boller and Hodge, afterward changed, through the admission of Howard C. Baird, M. Am. Soc. C. E., to Boller, Hodge and Baird. Following the death of Mr. Boller in 1912, the firm name was changed to Hodge and Baird.

During this period of a quarter of a century the work for which Mr. Hodge was largely responsible covered a wide field, embracing noteworthy structures in many parts of the world. Among these were the sightly Great Northern Railroad Bridge, at Duluth, Minn.; the Choctaw, Oklahoma and Gulf Railroad Bridge, at Little Rock, Ark., the pleasing design of which stands as a monument to his instinct for good taste; all bridges for the National Railroad Company of Mexico and for several South American companies, among which were the Brazil, Cerro de Pasco, Bolivian Central, and Madeira-Mamoré Railways; all bridges for the Philippine Railways and Manila Railway; the Riverside Viaduct at 96th Street and the Melrose Avenue Viaduct, in New York City; the bridges over the Connecticut River at Saybrook and East Haddam; and all bridges for the Wabash-Pittsburg Terminal Company, including the impressive cantilever bridges of that company over the Ohio and Monongahela Rivers, the latter having a span of 812 ft., which was the longest railroad span then in existence with the exception of the Forth Bridge. His crowning work was the great Municipal Bridge over the Mississippi River, at St. Louis, Mo., in which his initiative was notably displayed in the use of nickel steel for the main members of the exceptionally long simple channel spans.

In an advisory or consulting capacity Mr. Hodge's genius was utilized on the Blackwell's Island and Manhattan East River Bridges of the City of New York; the rehabilitation of the elevated lines of the Brooklyn Rapid Transit Company; the rebuilding of the Quebec Bridge after the collapse of the original structure; the Singer and Metropolitan Towers, in New York City; and studies and investigations for the proposed great interstate bridge over the North River at New York City. He was, at the time of his death, a member of the Board of Consulting Engineers for the proposed vehicular tunnel under the North River, between Lower Manhattan and Jersey City, N. J.

It is not only by this multitude of examples of his engineering skill that the professional work of Mr. Hodge is to be judged. Never seeking office, it was with reluctance that he consented, through a sense of duty and at great personal sacrifice, to accept a place on the Public Service Commission of the New York District proffered to him by Governor Whitman in January, 1916. His peculiar function as a Commissioner was to supervise the construction of the great subway extensions then in progress, as well as to deal with many matters of a regulatory nature. In this trying place he revealed fearlessness and powers of decision which won for him the renewed admiration of his friends and the respect and support of his colleagues, the press, and the community at large. His remarkable success as a Commissioner went far to support the claim that the engineer of character, experience, and administrative capacity is ideally suited for high public office.

The entry of the United States into the World War brought a ready response from Mr. Hodge, who sometime before had patriotically volunteered for and received a commission in the Engineer Officers' Reserve Corps. Governor Whitman felt that the subway situation in New York City was such that Mr. Hodge owed his first duty to the State, but, later, he withdrew his opposition to and accepted the resignation of Mr. Hodge, who sailed for France with the rank of Major, in July, 1917.

From this time until his discharge Col. Hodge rendered notable service to his country, first in charge of the design of railroad structures for the rapidly expanding transportation needs of the Army in France, then as Manager of Roads, and, finally, as Assistant Chief Engineer of the Army in charge of military bridges. He was promoted to the rank of Lieutenant-Colonel on October 26th, 1917, and to Colonel on August 13th, 1918, and received his honorable discharge on January 22d, 1919, soon after his return to the United States.

In the months that followed Col. Hodge entered vigorously into the rebuilding of his professional practice, but his friends noticed a change for the worse in his physical condition, beyond doubt brought about by his experiences in the Army. His sudden death, however, on December 21st, 1919, came as an unexpected shock to them.

Col. Hodge was a man of commanding figure, tall and well proportioned, with features that reflected a rare combination of strength and kindliness. His manners were always courteous and marked with the frankness and sincerity that command confidence and respect. Humor to an unusual degree was inherent in his nature and smoothed not only his own path through life but also the rugged roads of his friends, who never looked to him in vain for warm sympathy and helpful advice. To quote the words of Tennyson he was:

> "That tower of strength
> Which stood four-square to all the winds that blew."

Mentally, spiritually, physically, he truly was a man of mark, loved for his warm humanity and lofty ideals, admired for his commanding ability and strength of purpose, and respected for his straight thinking, sterling integrity, and fidelity to duty.

Col. Hodge was married on December 14th, 1897, to Sarah Cunningham Mills, only child of George Mills, of Savannah, Ga., who survives him.

He was a Trustee of Rensselaer Polytechnic Institute, from which he received the degree of Doctor of Engineering in 1918, a member of the Council of New York University, a Director of Princeton Theological Seminary, and a Director of the American Church in Paris. He was also a member of the Board of Foreign Missions of the Presbyterian Church and of the Board of Managers of the Knickerbocker Hospital of New York City, and a Governor of "Chester Crest", Mount Vernon, a home for intemperate men.

In his profession, he was a member of the American Institute of Consulting Engineers, in which he was a Past Director, the Canadian Society of Civil Engineers and the Institution of Civil Engineers of Great Britain. He was also a Veteran of the Seventh Regiment, and Secretary of the Associates of the Engineer Corps of Company K, Seventh Regiment, National Guard, New York; a member of the Citizens' Union of New York City; and a member of the Chamber of Commerce of the State of New York. His clubs were the Century, University, and Downtown of New York City.

Col. Hodge was elected a Junior of the American Society of Civil Engineers on January 5th, 1887, and a Member on October 2d, 1895. He served as a Director of the Society from 1913 to 1915, inclusive.

ROBERT WINTHROP PRATT, M. Am. Soc. C. E.*

DIED FEBRUARY 2D, 1920.

Robert Winthrop Pratt was born on December 23d, 1876, in Brookline, Mass. He was descended from old New England families, his father—a descendant of John Alden—being Robert Winthrop Pratt, and his mother, Grace (Kellogg), Pratt.

Mr. Pratt's early education was obtained in the public schools of Boston, while his technical education was acquired at the Massachusetts Institute of Technology, from which he was graduated as a Civil Engineer in 1896.

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* Memoir prepared by Robert Hoffmann and W. H. Dittoe, Members, Am. Soc. C. E.

After his graduation, Mr. Pratt began his practical engineering experience with the Boston and Albany Railroad. After about a year of railroad work, he left this field and started his career in sanitary engineering as Assistant Engineer with the Massachusetts State Board of Health. He remained with the State Board of Health for four years and then moved to Ohio, where he was engaged as Chief Engineer of the Ohio State Board of Health, holding this position from 1903 to 1911. During the early years of his work in Ohio, he also supervised for the Federal Government the gauging of stream flows in Ohio streams. This work was well performed and has proved to be of considerable value.

During one year of his connection with the Ohio Board of Health, namely 1909-10, Mr. Pratt was given a leave of absence to permit him to visit Havana as Consulting Engineer for the Cuban Government, in connection with the design of water supply and sewerage systems for several Cuban cities.

In October, 1911, Mr. Pratt left his position with the State Board of Health and moved to Cleveland, Ohio, where he became Special Sanitary Engineer for the latter city, and where he also began his private practice as Consulting Sanitary Engineer.

In connection with his work in Cleveland, he directed the tests and investigations which were conducted preliminary to designing the sewage disposal plants for the city. The early studies and general plans for the Cleveland Sewage Disposal System were also carried on under Mr. Pratt's general direction. During this same period, he also acted as Consulting Engineer for the Water Department, in connection with the design of the water filtration plant.

Mr. Pratt's professional life was an exceedingly busy one, and many places in Ohio and elsewhere are supplied with sewerage or water systems and with treatment plants built under his direction. He had also prepared a number of important reports on water and sewerage projects, of which the preliminary studies and report on the Toledo, Ohio, sewerage problem and his investigation, tests, and report on the proposed filtration of the water supply of Detroit, Mich., may be mentioned as of special importance.

The World War found Mr. Pratt particularly busy in connection with engineering work for the Chillicothe Cantonment and with industrial housing developments.

He had prepared many printed reports in connection with his Board of Health work as well as descriptions of work designed by himself. He was joint author of the well-known book on "Sewage Disposal", by Messrs. L. P. Kinnicut, C.-E. A. Winslow, and R. Winthrop Pratt.

Mr. Pratt had a fine, pleasing personality and was a most agreeable associate, socially and in business. He had a faculty of taking a broad

view of things which helped him wonderfully in matters coming to his attention. He had high ideals of engineering ethics which he practiced himself and expected others to observe. Through his untimely death, which was due to pneumonia and occurred on February 2d, 1920, after only a week's illness, the Engineering Profession loses a valued member and his closer acquaintances a true and faithful friend.

In June, 1903, he was married to Elizabeth Southwick, of New York City, who, with a family of two sons and two daughters, survives him.

Mr. Pratt was elected a Member of the American Society of Civil Engineers on June 6th, 1911.

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